12/31/2018

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Technical Reference User Manual (TRM)

Measure Savings Algorithms and Cost Assumptions

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Efficiency Vermont Technical Reference Manual

1 Introduction

1.1 Purpose of Technical Reference Manual

This Technical Reference Manual (TRM) provides descriptions of energy efficiency measures implemented by Efficiency Vermont's programs together with all the necessary algorithms and default assumptions for estimating the energy (both electric and fossil fuel) and peak electric capacity impacts. In addition, all parameters required for the application of cost-effectiveness tests (such as loadshapes, costs and lifetimes) are provided.

The manual is made up of *characterizations* which document all assumptions for a particular efficient technology. Within each characterization, there may be one or many specific sets of assumptions that characterize a specific application (e.g. multiple efficiency levels, fuels, capacity ranges, etc.) or technology type (e.g. various LED fixture types) all of which share the same algorithm, but where one or more inputs may be variant.

1.2 Use and Application of the TRM

1.2.1 Claiming Savings and Cost-Effectiveness Calculations

The TRM is the system of record for claiming savings and performing cost effectiveness tests for the efficiency measures and applications characterized and installed within a particular program year.

The primary cost-effectiveness test used by Efficiency Vermont to evaluate the performance of efficiency measures is the *Societal Cost Test* (SCT), as described in the California Standard Practice Manual[1]. A positive cost-effective test result (or screening) is required for overall portfolio, total program, and customer project level screening, with some exceptions for low-income programs, pilots, and new technologies that require heightened program support. Components or measures within a project may be non-cost-effective, particularly if required for health and safety, so long as the project, program or portfolio screens as a whole.

All components needed to perform a cost-effectiveness test are found within the TRM and the calculations are performed through application of a Screening API (Application Programming Interface) accessed through Efficiency Vermont's analysis and tracking system *Tracker*.

1.2.2 Annual Savings Verification

At the end of each program year, a version of the TRM containing all measures that were active at any time during that program year is saved and used as the basis for corroborating Efficiency Vermont savings

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[1] 'California Standard Proactive Manual, Economic Analysis of Demand-Side Programs and Projects', October 2001.

claims during the annual evaluation of the ratepayer-funded programs in Vermont, referred to as the Savings Verification process.

1.2.3 Portfolio Planning and Evaluation (Demand Resource Plan)

The TRM also provides the basis for first year assumptions within the implementation of portfolio modelling exercises including the Demand Resource Plan, filed every three years. The TRM characterizations generally do not provide documentation of future year adjustments to first year assumptions, though in instances where such adjustments are known (e.g. forthcoming Federal Standard changes) they may be documented and planned for. Therefore where modeling is required for multiple years in to the future, additional assumptions concerning future year changes need to be documented outside of the TRM and within the specific application used for forecasting and portfolio screening.

1.2.4 Forward Capacity Market

Efficiency Vermont is an active bidder into the ISO-New England (ISO-NE) *Forward Capacity Market (FCM)*. The FCM is an annual Auction where bidders commit to the supply of future capacity in exchange for a market-priced payment, with a goal to ensuring that the New England power grid will have sufficient resources to meet future demand. Demand-side efficiency programs that can guarantee the generation of electricity savings during the ISO-NE defined peak period can be included in the market.

The TRM is a major component of the Measurement and Verification (M&V) plan that is required in order to qualify to participate in the FCM auction. Efficiency Vermont submits a new version of the plan with a copy of the active TRM to ISO-NE for review every year.

1.3 Prescriptive v Custom Measures

The primary objective of the TRM is to document the savings assumptions for *prescriptive* measures – i.e. those measures with a high volume and with relatively low per unit savings, where individual custom calculations would be cost-prohibitive, or where the likely variation of savings is low and/or the availability of input data is prohibitive to a custom application of the measure.

However there is a spectrum of “prescriptiveness” across characterizations, ranging from those with a single deemed savings value, to those semi-custom characterizations where multiple inputs are required for each application. The TRM may also be used to document *custom* protocols and/or provide one or more of the key cost-effective test inputs that cannot be collected on site (such as lifetime) for those measures that are evaluated outside of the TRM (e.g. through modeling software, metering etc).

When evaluating which form a particular measure will take, the balance of the cost of implementation against the corresponding potential accuracy of the savings estimate is considered.

1.4 Development and Review Process

The manual is maintained by members of Efficiency Vermont’s Evaluation, Measurement, and Verification (EM&V) department. There are four main scenarios when changes are made to the TRM:

1. New characterizations are created whenever a new technology is ready for implementation and where savings will be claimed through a prescriptive process.
2. Existing measures are updated with new information, e.g. for a Federal Standard or efficient specification update, following publication of new evaluation results that provide an improved basis for existing assumptions, or where new measure implementation methods require additional variable assumptions.
3. Existing measures are updated to fix errors or provide improved clarifications.
4. Reliability updates - Any characterization that has not received any update for three years is automatically included in a review process to check for continued validity, consistency with other measures, accuracy of assumptions and whether any new evaluation results should be considered. Changes arising from the reliability review are activated in the subsequent program year.

1.4.1 Review Processs

Once a characterization draft is complete an initial screening of the measure is completed to assess whether the assumptions lead to a cost-effective application. The measure is then reviewed internally by VEIC EM&V staff, before being sent to the Vermont Public Service Department for review. When all comments are received and resolved, the measure is made *Active* in the TRM on its Effective Date and all prescriptive measures installed from that date will utilize the new assumptions.

1.4.2 Application of Updates

Whenever possible, characterizations are made active after the Internal and External review process described above is complete, such that the new assumptions are applied only for measures installed prospectively. However, when considered appropriate (e.g. to align with the effective date of a specification change, or when fixing a significant error), the characterization change may be made *retroactively* and any prior installation in the present program year will be adjusted accordingly.

2 Characterization Structure

The TRM contents are organized by Program and then End Use. However where the same technology is supported in multiple programs, and where the characterization methodology and algorithm(s) are similar, some characterizations have been consolidated into one, providing alternative assumptions for each program type where appropriate.

Each characterization is made up of the following components:

2.1 Referenced Documents

All referenced documents are listed with a hyperlink to open the document. These may include analysis spreadsheets used to calculate the savings, evaluations, and memos.

2.2 Descriptions

2.2.1 Measure Description

The Measure Description section includes a general description of the measure, how it saves energy, and the specific *reporting category*(s) and delivery mechanism(s) being characterized. It will be clearly stated whether the measure is intended to represent a Market Opportunity (i.e. time of replacement or new construction), Early Replacement, Retrofit or Early Retirement application, and the method of implementation (e.g. Up-, Mid- or Down-stream, Direct Install, or Building Performance Programs). See definitions in section 3.2 and 3.3.

2.2.2 Baseline Efficiencies

The baseline assumptions will be clearly defined. For a Market Opportunity measure the baseline is generally based on one of two approaches: either a minimum code or standard efficiency level, or a market based estimate representing what is most common in the marketplace, often determined through a baseline study.

For Early Replacement , Retrofit and Early Retirement applications the baseline is generally the existing equipment as it is currently operated, or as it would be expected to be operated in the absence of the energy efficiency measure/equipment.

2.2.3 Efficient Equipment

The Efficient Equipment section includes a clear definition of the criteria by which it will be determined whether equipment qualifies as efficient. This may include specific technologies, minimum efficiencies, energy efficiency standards (such as ENERGY STAR or CEE Tiers), or other criteria.

2.3 Algorithms

2.3.1 Algorithm Outputs

The Algorithm section provides mathematical formulas for the impact of the measure on each of the following as appropriate:

i. Electric Demand Savings: calculation of the first year connected load reduction (or penalty). This is used to estimate the Summer and Winter *coincident peak kW* reduction, by multiplying with the coincidence factors from the measure's loadshape. This usually represents the maximum kW reduction associated with the measure, but some loadshapes deliberately assume that it represents the average kW reduction.

ii. Electric Energy Savings: calculation of the first year total kWh saved (or penalty) per unit.

iii. Fossil Fuel(s) Savings: calculation of first year MMBtu savings (or penalty) or any applicable fossil fuel (natural gas, liquefied petroleum gas (propane), distillate, kerosene, wood (logs, pellets or chips)).

iv. Water Savings: calculation of first year water savings (or penalty)

2.3.2 Algorithm Variables

Each variable within an algorithm will be listed and defined. Variables can take the form of Constants, Deemed Values or Inputs:

i. Constants - values that are universal, such as conversion factors that will have the same values in all contexts.
ii. Deemed Values - variables for which an average, typical, or representative value has been determined for the measure or application in question. In many cases there may be multiple deemed values provided for different applications, efficiency levels, installation locations etc. Each unique combination of Deemed Values will be screened separately and use a different *Item Code* to track installation; see section 2.8.2 for more information. Each deemed value will have a source reference specifying the basis of the assumption(s). If the values were calculated, the details of the calculation will be provided either in a footnote or in an attached referenced document.
iii. Inputs – custom values that are input into the algorithm directly based on information collected onsite or provided on a prescriptive form or invoice. A default value may be provided for instances where the input data is missing or incomplete.

Depending on the construction of the algorithm and its variables, each measure output may be a single deemed value, multiple deemed values depending on one or more variable, or be a custom output requiring calculation dependent on one or more Inputs.

2.3.3 In Service and Leakage Rates (where applicable)

Many Market Opportunity characterizations include variables to address the likelihood that a purchased measure will end up being installed within the Vermont service territory:

- In Service Rate (ISR): Representing the assumed proportion of all sales that end up getting installed. This is particularly important for measures that are provided free or at low cost to the customer.

- Leakage Rates: Representing the assumed proportion of sales through the program that are installed outside of the Vermont service territory and so are ineligible to be counted towards efficiency goals.

2.3.4 Mid Life Baseline Adjustment (where applicable)

In some characterizations, it is appropriate to apply a mid-life adjustment to the kWh and/or MMBtu savings at some point within the life of a measure. This affects the lifetime savings of the measure as well as the Net Present Value. Possible scenarios requiring this adjustment are:

i. Early replacement measures where the first X years’ savings are from the existing equipment to the new efficient equipment while the following Y years’ savings are from a hypothetical new baseline unit to the efficient equipment.

ii. Situations where the baseline alters one or more times during the life of the efficient measure, resulting in a change to the assumed baseline efficiency, for example, incorporation of the impact of EISA lighting standards on baseline replacement lamp efficacies within the lifetime of an LED installation.

When such an adjustment is required, the characterization will specify the adjustment percentage (i.e. ‘new savings after adjustment’ / ‘first year savings’) plus the timing of the adjustment (either number of years from installation or to occur in a specific future year).

2.4 Loadshapes

Every measure with electric savings has a loadshape provided. Each loadshape is made up of six percentage values; four energy periods (totaling 100%) that are multiplied by the first year electric energy savings and applied to a unique set of *avoided costs* (for Winter Peak, Winter Off-Peak, Summer Peak and Summer Off-Peak), and two *coincidence factors* (Winter and Summer) corresponding to the percent of kW savings that is concurrent with Vermont’s seasonal peak. Loadshapes also include an assumed hours of use which is used in determining the loadshape, but may be different to the hours used in a measure’s savings calculation.

Active Efficiency Vermont loadshapes can be found here.

2.4.1 Efficiency Vermont Avoided Cost Period Definitions

As of January 1, 2016, Efficiency Vermont is using the following avoided costs energy periods based on the Avoided Energy Supply Costs in New England: 2015 Report prepared for the Avoided-Energy-Supply-Component (AESC) Study. The coincident peak periods are based on ISO New England performance hours for the forward capacity market.

Winter Peak Energy: 7AM - 11PM, weekdays, October to May;

Winter Off-Peak Energy: 11PM - 7AM, weekdays, all weekend hours, October to May;

Summer Peak Energy: 7AM - 11PM, weekdays, June to September;

Summer Off-Peak Energy: 11PM - 7AM weekdays, all weekend hours, June to September.

Summer Gen. Capacity: 1PM-5PM, weekday, non-holiday, June-August

Winter Gen. Capacity: 5PM-7PM, weekday, non-holiday, December-January

2.5 Net Savings Factors

The characterization provides the *Gross Savings* estimate, i.e. the estimated savings experienced at the customer's meter as a result of the energy efficiency measure. To complete the cost effectiveness tests, it is necessary to convert the Gross Savings into *Net Savings*, i.e. the estimated savings at generation and attributable to the program. Net Savings is calculated as follows:

$$\text{NetkWh} = \sum(\text{netkWh}_i)$$

$$\text{netkWh}_i = \Delta\text{kWh} \times (1+\text{LLF}_i) \times (\text{FR} + \text{SPL} - 1) \times \text{RPF}_i$$

$$\text{netkW}_j = \Delta\text{kW} \times (1+\text{LLF}_j) \times (\text{FR} + \text{SPL} - 1) \times \text{CF}_j$$

Where:

netkWh$_i$ = kWh energy savings at generation-level, net of free riders and persistence, and including spillover, for period *i* (Winter On-Peak, Winter Off-Peak, Summer On-Peak and Summer Off-Peak)

i = subscript used to denote variable energy rating periods (Winter Peak, Winter Off-Peak, Summer Peak, Summer Off-Peak).

ΔkWh = gross customer annual kWh savings for the measure

LLF$_i$ = line loss factor for period *i*. The Line Loss factor represents the marginal electricity losses from the generator to the customer – expressed as a percent of meter-level savings.

FR = *Freeridership factor*, as presented in the measure characterizations. The Freeridership factor is equal to 1 minus the percent freeridership. For example, if it is assumed that 10% of measure installations are freeriders, FR will be equal to 0.9.

SPL = *Spillover factor*, as presented in the measure characterizations. The Spillover factor is equal to 1 plus the percent spillover. For example, if it is assumed that a measure has 5% spillover, SPL will be equal to 1.05.

RPF$_i$ = rating period factor for period *i* [as provided by the loadshape]

netkW$_j$ = kW demand savings, net of free riders and persistence, and including spillover, for season *j*

j = subscript used to denote variable seasonal peaks (Summer or Winter).

ΔkW = gross customer connected load kW savings for the measure

LLF$_j$ = line loss factor for seasonal peak *j*

CF$_j$ = the percent of kW savings that is concurrent with Vermont's seasonal peak, for season *j* [as provided by the loadshape]

2.5.1 Line Loss Factors

All of the parameters above except *Line Loss factors (LLF)* are provided in each measure characterization. The LLFs do not vary by measure, but by costing period, and are provided in the following table[2]. Note the "Including PTF" values are used in the Net Savings calculation above:

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[2] From document titled Vermont Public Service Board Order: EEU AVOIDED COSTS FOR 2016-2017 TIME PERIOD

Distribution Line Loss Values - Efficiency Vermont		
Marginal Losses by Costing Period		
	not including PTF	*including PTF*
Winter Peak	11.8%	14.8%
Winter Off-Peak	9.8%	12.3%
Summer Peak	11.9%	15.0%
Summer Off-Peak	9.5%	11.9%
Average Losses at Peak Hour		
	not including PTF	*including PTF*
Winter	9.0%	11.3%
Summer	8.9%	11.2%

2.5.2 Measure Codes and Item Codes

Each characterization will have one or more associated *Measure Codes*, used to identify the general technology. A single measure code may represent many different (but related) specific technologies, and they all will share the same Net to Gross Factors (Freerider and Spillover rates) within each program *Track*.

Measure codes are eight-character alpha-numeric codes, consisting of the following:

- The first three digits represent the end use being impacted by the measure.
- The remaining five digits represent the measure, application and/or efficiency level as appropriate.

For example: CKLC3WRP

CKL: Cooking and Laundry end use

C3: CEE Tier 3

WRP: Clothes Washer

For example: LFHEXLED

LFH: Lighting Hardwired Fixture end use

EX: Exterior

LED: LED Fixture Type

Each unique output from a characterization's algorithm, using a combination of all the deemed prescriptive assumptions, will also have a unique Item Code prescribed. Item Codes are alpha-

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numeric codes that identify a specific prescriptive measure, market, implementation method and/or specification. For example ‘BES-XTR-F’ is an ‘LED Exterior Fixtures, 2,001-5,000 lumens’ and ‘EPT3FCW’ is a ‘Residential Efficient Products Front Loading Clothes Washer (CEE Tier 3)’. Many characterizations do not currently display Item codes.

2.6 Lifetimes

The measure life quantifies the number of years (or hours) that the new high efficiency equipment is expected to function and provide the savings characterized. It is often based on the rated engineering life of the equipment, but is sometimes adjusted based on the expected *Persistence* of the savings. Persistence represents the fraction of gross measure savings obtained over the measure life. For measures where equipment tends to be removed, made inoperative, overridden or poorly maintained before the end of its rated life (e.g., controls or economizers), applying a persistence factor to adjust the measure life may be necessary. Persistence factors are applied directly to the engineering life to determine an adjusted measure life within the TRM characterization.

For early replacement/retrofit measures where a mid-life adjustment is prescribed, the expected remaining life of the existing unit will also be provided.

2.7 Measure Cost

The measure cost represents the difference in cost between the baseline condition and the efficient measure.

For a Market Opportunity baseline, the measure cost will represent an incremental cost, or the difference between the purchase and installation of the baseline equipment and the purchase and installation of the efficient equipment. Installation costs only need to be included where there is a difference between baseline and efficient installation costs.

For an Early Replacement or Retrofit measure, the measure cost is the full cost of purchase and installation, including any cost of removing and disposing of the existing equipment. The TRM will also provide the estimated purchase and installation cost of the hypothetical deferred baseline (i.e. the replacement of existing equipment that would have occurred had the efficient measure not already replaced it) and the timing of that deferred replacement cost consistent with the timing of the mid-life adjustment.

For an Early Retirement measure, the measure cost is the full cost of collection and disposal of the existing equipment.

2.8 Operation and Maintenance Cost Adjustments

For any measure where there is forecast to be a difference in the operation and maintenance (O&M) costs (including replacement of component parts such as lamps) between the baseline and the efficient case, these costs are described within the characterization. The costs and lives for up to two components each for the baseline and efficient case can be provided.

For a select number of measures, a regular O&M cost may change significantly over the life of a measure (e.g. the cost of replacement baseline bulbs before and after the impact of EISA legislation). In these cases, an equivalent annualized payment may be calculated that results in the same net present value as the actual stream of costs over the measure life.

2.9 Reference Tables

Many measures include one or more reference tables. These tables often document multiple inputs for characterizations with a large number of specific technology types (e.g. LED light fixtures) and/or the savings outputs for each unique set of deemed variables with the specified measure or item code.

2.10 Footnotes & Citations

The final section of the characterization contains footnotes which provide additional context or explanation and/or referenced citations for the assumptions provided, all of which are attached in the Reference Documents Section.

3 General Concepts and Assumptions

3.1 Reporting Category and Track Definitions

The current Efficiency Vermont Reporting Categories are presented below. These are specified with a four digit MAS90Job number:

MAS90Job	Description
6012	Business Retrofit
6013	C & I Equipment Replacement
6014	C & I New Construction
6015	Customer Credit
6017	Low Income Multi Family Retrofit
6018	Low Income Multi Family New Construction
6019	Market Rate Multi Family New Construction
6020	Market Rate Multi Family Retrofit
6032	Energy Efficient Products
6034	Low Income Single Family Homes

6036	Existing Homes
6038	Residential New Construction Single Family Homes
6041	Low Income Single Family New Construction

Within each reporting category are subcategories or Tracks which provide additional context of the project type. A list of Tracks used within the TRM can be found here.

3.2 Measure Calculation Types

There are five distinct measure calculation types described below, each with key differences in the determination of baseline.

Program	Definition
Market Opportunity: Time of Sale	Definition: A program in which the customer is incentivized to purchase or install higher efficiency equipment than they would have done if the program had not existed. Baseline Case = New base level equipment, often corresponding to a federal standard or at a level representing standard industry practice. Efficient Case = New, high efficiency equipment meeting a program specified level.
Market Opportunity: New Construction	Definition: A program that intervenes during building design to support the use of more-efficient equipment and construction practices. Baseline = New base level equipment at the efficiency level defined in the applicable Building Energy code, federal standard level or standard practice as derived by baseline studies. Efficient Case = The program's prescribed level of building specification.
Early Replacement	Definition: A program that replaces existing equipment before the end of its expected life. To qualify as early replacement, there needs to have been prior contact with the customer replacing functioning equipment – e.g. during on site audit or through prior phone/email contacts, and evidence must be provided that the unit is being replaced to achieve energy savings. Baseline = Dual; for the expected remaining useful life of the existing equipment the baseline is the efficiency of the existing equipment and then shifts to represent new baseline equipment. Efficient Case = New, high efficiency equipment meeting a program specified level.
Retrofit	Definition: A program that upgrades or enhances existing equipment. Baseline = Existing equipment or the existing condition of the building or equipment. A single baseline applies over the measure's life. Efficient Case = Either new, high efficiency equipment or modifications of existing equipment to make it operate more efficiently.
Early Retirement	Definition: A program that retires duplicative equipment before its expected life is over. Baseline = The existing equipment, which is retired and not replaced.

Program	Definition
	Efficient Case = Since the unit is retired, the efficient case consumption will be zero.

3.3 Program Delivery / Implementation Type Definitions

Presented below are descriptions of common methodologies that are used by programs to implement measures, delivering the energy saving technology(s) or practice(s) to their customers:

- Upstream: Providing incentives to manufacturers to lower the cost to the consumer of an efficient option or to invest in R&D or production of more efficient options at the start of a supply channel or to pass along the discount to distributors or retailers to decrease their costs and increase adoption and stocking.
- Midstream: Providing incentives to distributors or retailers to encourage the stocking and marketing of the efficient options and/or lower the cost to the consumer.
- Downstream: Providing incentives directly to the end user or consumer through coupons or rebates.
- Direct Install: A program where measures are installed during a site visit by a staff member or contractor.
- Free product: Product is provided to customers free of charge. This could be during a promotional event, left with customers after a site visit or through the mail.
- Efficiency Kits: A selection of low cost energy saving products are provided to customers for free or a low charge. Often kits are required to be requested to increase likelihood of installation.
- Home Energy Reports: Electricity bill inserts that provide information on a residences relative consumption compared to similar homes in the local area to encourage behavioral change and/or efficient measure purchases.

3.4 Interactive effects

In some characterizations, the savings algorithm(s) include factors to estimate the impacts of interactions of the measures with other end uses, for example, cooling and heating effects from interior lighting waste heat. The TRM does not, however, provide a methodology for accounting for interactions between measures installed concurrently.

In custom projects, Efficiency Vermont Energy Consultants perform site-specific customized calculations to account for interactions between measures (e.g., individual savings from installation of window film and replacement of a chiller are not additive because the first measure reduces the cooling load met by the second measure). If a project includes both prescriptive and custom measures, the prescriptive measures will be calculated in the normal manner and assumed to be installed prior to determining the impacts of the custom measures. To determine interacting custom measure savings, Energy Consultants calculate measure impacts in descending order of measure life (i.e., starting with the longest lived measure), assuming each prior measure is installed before calculation of the savings from the next.

3.5 Heating and Cooling Degree-Day Data

Where a characterization's variable assumptions are sensitive to outdoor temperatures, heating and cooling degree days (HCDDs) are often used to calculate site or region specific assumptions. HCDDs are calculated using TMY3 data from the Department of Energy National Oceanic and Atmospheric Administration (NOAA).

3.6 Inflation and Discount Rates

The Vermont screening tool calculates the *Net Present Value (NPV)* of an efficiency measure by comparing the initial measure cost and any future cost impacts with the present value of the energy savings over the lifetime of the measure. The following financial assumptions are used in the calculation of present value:

3.6.1 Real Discount Rate

The value of all future costs or savings are discounted to the *Program Year* using the Real Discount Rate (RDR) of 3.0%. This rate is currently affirmed in a 2015 Public Service Board ruling EEU-2015-04 "Order RE: EEU Avoided Costs for 2016-2017 Time Period".

3.6.2 Future Inflation Rate

The projected future inflation rate, used for adjusting measure costs, Operation and Maintenance costs, and deferred baseline replacement costs from the Program Year to the *Base Year* (defined as the first year of the current three year performance period). Current value is 2.0% based upon rates used in AESC 2015 Update: "10 year treasury note - Composite of CBO for 2017 thru 2026 and AEO 2016 for 2017 thru 2031".

3.6.3 Inflation Rate to Base Year

This is only used to adjust future avoided costs to the Base Year. It is based on the escalation rates used to determine the Avoided costs from the 2015 Association of Energy Service Companies (AESC) report and is currently 1.51%.

3.7 Stipulated Database Adjustments

3.7.1 RES / C&I Split for EP Retail Lighting

For upstream lighting programs delivered through Efficient Products, a specified percentage of purchases are assumed to be Residential and the remainder are assumed to be Commercial, with the relevant characterization assumptions applied to each portion. The current split is set at 89.5% Residential and 10.5% Commercial, as determined through a TAG agreement.

3.7.2 Upstream/Midstream Reconciliation

To avoid double counting of savings where measures are supported both Upstream (incentive provided to suppliers of equipment) and by a Midstream (retailers) or downstream (end-user) incentives, reconciliation procedures are in place to deduct any duplication of savings. These procedures are documented in the Efficiency Vermont Business Process Manual section of the Vine here.

4 Glossary of Terms

Active Date: The date from which a particular measure characterization is active and the assumptions documented are applied to new installations.

Avoided Costs: The forecasted marginal cost of generation of electric or fossil energy that an energy efficiency measure will save over its lifetime.

Base Year: The first year of the current three year Efficiency Vermont performance period. The value of all costs and savings are discounted to represent this base year's dollars.

Characterizations: Documentation of all the necessary cost-effectiveness screening assumptions for a particular measure or group of similar measures.

Coincidence Factors: Coincidence factors represent the fraction of connected load expected to be coincident with a particular system peak period, on a diversified basis. Coincidence factors are provided for summer and winter peak periods.

Custom: A project or measure that requires multiple site specific inputs to complex modeling analyses, or requires pre and post metering to quantify the savings associated with it.

Environmental Externalities: The prescribing of an economic value to the environmental impact of the production (or saving) of energy.

Expected Remaining Life: The assumed remaining life of existing equipment that is being replaced for efficiency reasons prior to the end of its natural life.

Forward Capacity Market (FCM): A market based auction where bidders commit to the supply of (or savings of) future capacity in exchange for a market-priced payment.

Freeridership Factor: The fraction of gross program savings that would have occurred without the programs involvement.

Gross Savings: The estimated impact of an efficiency measure at the customer's meter(s). When multiplied by the customer's energy rates the impact on their energy bills is determined.

Item Code: An alpha-numeric codes, up to 16 characters in length, which identifies a specific prescriptive measure, market, implementation method and/or specification.

Line Loss Factors (LLF): The marginal electricity losses from the generator to the customer – expressed as a percent of meter-level savings. The Energy Line Loss Factors vary by period. The Peak Line Loss Factors reflect losses at the time of system peak, and are shown for the two seasons of the year (Summer and Winter). Line loss factors are the same for all measures.

Low Income Adder: Adjustment to account for the greater benefits resulting from energy savings in low-income sectors because the energy bill-to-income ratio is higher relative to other sectors and because non-energy benefits for comfort, health, and safety appear to be greater in that sector as well.

Measure Code: An eight-character alpha-numeric code used to identify a general measure technology and sharing the same Net to Gross Factors (Freerider and Spillover rates) within each program Track.

Net Present Value (NPV): The delta between the value of all costs and savings over the lifetime of an efficiency measure in the base year dollars.

Net Savings: The estimated impact of an efficiency measure at generation that can be attributed to the efficiency program. Calculated by incorporating the line loss factors and freeridership and spillover rates.

Non-Energy Benefit/Impacts (NEB/NEI): Additional outcomes of energy efficiency activities relating to participant, utility or societal impacts such as comfort, health, durability, productivity, property values etc. Note that Operation and Maintenance and water impacts are calculated separately and not included in any NEB adder.

Persistence: Adjustments used when appropriate to reduce lifetime savings in recognition that the measure may not provide the calculated annual savings for the entire rated engineering life of the unit.

Prescriptive: An efficiency measure that is considered appropriate to assume consistent prescribed savings for each specified application, rather than perform a custom calculation for each installation.

Program Year: The year in which an efficiency measure was reported. Efficiency Vermont program years run on a calendar year basis.

Reliability Review: An annual review process for characterizations that have not had a recent update to ensure ongoing validity, consistency and to update with new evaluation results.

Retroactive: Application of a change to an existing characterization to measures already installed and claimed in a program year.

Societal Cost Test (SCT): The principal cost effectiveness test utilized by Efficiency Vermont to evaluate the value of an efficiency measure. The net benefit to society of the activities is based upon lifetime benefits (i.e. the societal avoided costs of energy savings, including externalities (environmental benefits) and other non-energy benefits over the life of a measure) minus lifetime costs (including measure cost, O&M costs (or benefits), risk discount (to account for risks associated with investments in supply-side resources that are avoided by investing in demand side management), and avoided replacement costs).

Spillover Factor: Savings attributable to the program, but generated by customers not directly participating.

Total Resource Benefits: The total present value of the electric energy savings (or increase), electric coincident peak demand reduction (or increase), fuel savings (or increase), and water use savings (or increase) over the lifetime of the measure. Note that TRB is *not* affected by any of the following: environmental externalities, non-energy benefits and low income adders, operations and maintenance costs, measure costs, or incentives.

Track: Classification and division of Reporting Categories into subgroups of similar implementation methods.

Efficient Compressors 40 hp and Below

Measure Number:	I-F-3 b
Portfolio:	EVT TRM Portfolio 2017-10
Status:	Active
Effective Date:	2018/1/1
End Date:	[None]
Program:	Business Energy Services
End Use:	Compressed Air

Update Summary

- Combined the three original excel analysis files into one file, removing the three original and uploading the new/revised workbook. Updated the corresponding footnotes and references accordingly.
- This measure was reviewed according to the 3-year reliability cycle and it was determined the existing assumptions and characterization approach for this measure are valid and requires no update at this time. The primary factors involved in the characterization of this measure are sourced from a DOE part-load curve study, examining compressed air load profiles in 50 facilities for various compressor types. This study was published in 2006, and through review of a number of current peer group jurisdictions, remains heavily referenced and sourced in compressed air measure characterization.

Referenced Documents

- Compressed Air Analysis

Description

Baseline compressors choke off the inlet air to modulate the compressor output, which is not efficient (Modulating). Efficient compressors use a variable speed drive on the motor to match output to the load. Savings are calculated using representative baseline and efficient demand numbers for compressor capacities according to the facility's load shape, and the number of hours the compressor runs at that capacity. Demand curves are as per DOE data for a Variable Speed compressor versus a Modulating compressor. This measure applies only to an individual compressor ≤ 40 hp.

Estimated Measure Impacts

Average Annual MWH Savings per unit	Average number of measures per year	Average annual MWH savings per year
20.0[1]		

Algorithms

Electric Demand Savings

ΔkW	$= \Delta kWh / HOURS$

Symbol Table

Electric Energy Savings

ΔkWh	$= 0.9 \times hp_{compressor} \times HOURS \times (CF_b - CF_e)$

Where:

ΔkW	=	gross customer annual kW savings for the measure
ΔkWh	=	gross customer annual kWh savings for the measure
CF_b	=	baseline compressor factor (see "Compressor Factors by Control Type" in Reference Tables section)
CF_e	=	efficient compressor factor (see "Compressor Factors by Control Type" in Reference Tables section)
HOURS	=	compressor total hours of operation (see Operating Hours section)
$hp_{compressor}$	=	compressor motor nominal hp

See "Compressed Air Analysis.xlsx" for algorithm details.

Baseline Efficiencies

The baseline equipment is a modulating compressor with blow down ≤ 40 hp.

High Efficiency

The high efficiency equipment is a compressor ≤ 40 hp with variable speed control.

Operating Hours

Single shift (8/5) – 1976 hours (7 AM – 3 PM, weekdays, minus some holidays and scheduled down time)

2-shift (16/5) – 3952 hours (7AM – 11 PM, weekdays, minus some holidays and scheduled down time)

3-shift (24/5) – 5928 hours (24 hours per day, weekdays, minus some holidays and scheduled down time)

4-shift (24/7) – 8320 hours (24 hours per day, 7 days a week minus some holidays and scheduled down time)

Load Shapes

Calculated demand impacts (kW) represent diversified kW demand savings over each typical hour that compressed air system is operating. Therefore, for shifts that totally encompass the peak capacity periods, the coincidence factor equals 100%. For shifts that only encompass a portion of the peak capacity period, the coincidence factor represents the portion of the peak capacity period included in the shift hours.

44b Indust. 1-shift (8/5) (e.g., comp. air)
45a Indust. 2-shift (16/5) (e.g., comp. air)
46a Indust. 3-shift (24/5) (e.g., comp. air)
47a Indust. 4-shift (24/7) (e.g., comp. air)

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
44	Indust. 1-shift (8/5) (e.g., comp. air)	Active	66.6 %	0.0 %	33.4 %	0.0 %	0.0 %	59.4 %
45	Indust. 2-shift (16/5) (e.g., comp. air)	Active	62.4 %	4.2 %	31.3 %	2.1 %	95.0 %	95.0 %
46	Indust. 3-shift (24/5) (e.g., comp. air)	Active	44.4 %	22.2 %	22.3 %	11.1 %	95.0 %	95.0 %
47	Indust. 4-shift (24/7) (e.g., comp. air)	Active	31.7 %	34.9 %	15.9 %	17.5 %	95.0 %	95.0 %

Net Savings Factors

Measures

CMPCOMPR	Compressed air, compressor

Tracks [Base Track]

6013CUST [is base track]	Cust Equip Rpl
6013PRES [is base track]	Pres Equip Rpl

Persistence

The persistence factor is assumed to be one.

Lifetimes

10 years.

Analysis period is the same as the lifetime.

Measure Cost

Incremental Cost ($) = (127 x $hp_{compressor}$) + 1446

Where:

127 and 1446[2] = compressor motor nominal hp to incremental cost conversion factor and offset

$hp_{compressor}$ = compressor motor nominal hp

O&M Cost Adjustments

There are no operation and maintenance cost adjustments for this measure.

Fossil Fuel Description

There are no fossil-fuel algorithms or default values for this measure.

Incentive Level

The incentive for this measure is half the calculated incremental cost.

Reference Tables

Compressor Factors by Control Type[3]

Control Type	Compressor Factor
Modulating w/ BD	0.890
Variable speed drive	0.705

Footnotes

[1] Assumes 25 hp compressor with variable speed control running 2 shifts.

[2] Conversion factor and offset based on a linear regression analysis of the relationship between air compressor motor nominal horsepower and incremental cost. Several Vermont vendors were surveyed to determine the cost of equipment. See "Compressed Air Analysis.xlsx" for incremental cost details.

[3] Compressor factors were developed using DOE part load data for different compressor control types as well as load profiles from 50 facilities employing air compressors less than or equal to 40 hp. "See "Compressed Air Analysis.xlsx" for source data and calculations (The "variable speed drive" compressor factor has been adjusted up from the 0.675 presented in the analysis to 0.705 to account for the additional power draw of the VSD).

Cycling Dryers

Measure Number:	I-F-4 b
Portfolio:	EVT TRM Portfolio 2017-10
Status:	Active
Effective Date:	2018/1/1
End Date:	[None]
Program:	Business Energy Services
End Use:	Compressed Air

Update Summary

Measure was reviewed according to the 3-year reliability cycle:

- Updated the conversion factor for an average compressor's CFM to air dryer's kW from 0.0087 to 0.0079. I incorporated more air dryer data to develop a better estimate of an air dryer's power draw based on an air compressor's air flow ratings. The original values were being drawn from a statistically small sample of equipment operating data so I expanded the data set.
- Updated the energy savings algorithms by naming the default conversion factors a variable name instead of being a hard-coded number in the equation. I defined the variable and its default value in the variable definition section.
- Combined the three original excel analysis files into one file, removing the three original and uploading the new/revised workbook. Updated the corresponding footnotes and references accordingly.

Referenced Documents

- Compressed Air Analysis

Description

Use of a refrigerated dryer that cycles on and off as required by the demand for compressed air instead of running continuously. **This measure only applies to dryers with capacities of 600 cfm and below.** Larger dryers will be handled on a custom basis.

Estimated Measure Impacts

Average Annual MWH Savings per unit	Average number of measures per year	Average annual MWH savings per year
1.11[1]		

Algorithms

Electric Demand Savings

ΔkW	= ΔkWh / HOURS

Symbol Table

Electric Energy Savings

ΔkWh	$= ((\text{CFM per hp x hp}_{\text{compressor}}) \times \text{TF}_{\text{Dryer}} \times \text{HOURS} \times (1 - \text{APC})) \times \text{RTD}$

Where:

ΔkW	=	gross customer kW savings for the measure
ΔkWh	=	gross customer annual kWh savings for the measure
APC	=	Average % Capacity; average operating capacity of compressor (65%)[2]
CFM per hp	=	approximate compressor output CFM per compressor motor nominal hp (4)[3]
HOURS	=	compressor total hours of operation (see Operating Hours section)
$\text{hp}_{\text{compressor}}$	=	compressor motor nominal hp
RTD	=	Chilled Coil Response Time Derate (0.925) (from “Compessed Air Analysis.xlsx”)
TF_{Dryer}	=	compressor CFM to baseline dryer kW transformation factor (0.0079)[4]

See “Compressed Air Analysis.xlsx” for algorithm details.

Baseline Efficiencies

The baseline equipment is a non-cycling refrigerated air dryer with a capacity of 600 cfm or below.

High Efficiency

The high efficiency equipment is a cycling refrigerated air dryer with a capacity of 600 cfm or below.

Operating Hours

Single shift (8/5) – 1976 hours (7 AM – 3 PM, weekdays, minus some holidays and scheduled down time)

2-shift (16/5) – 3952 hours (7AM – 11 PM, weekdays, minus some holidays and scheduled down time)

3-shift (24/5) – 5928 hours (24 hours per day, weekdays, minus some holidays and scheduled down time)

4-shift (24/7) – 8320 hours (24 hours per day, 7 days a week minus some holidays and scheduled down time)

Load Shapes

44b Indust. 1-shift (8/5) (e.g., comp. air)
45a Indust. 2-shift (16/5) (e.g., comp. air)
46a Indust. 3-shift (24/5) (e.g., comp. air)
47a Indust. 4-shift (24/7) (e.g., comp. air)

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
44	Indust. 1-shift (8/5) (e.g., comp. air)	Active	66.6 %	0.0 %	33.4 %	0.0 %	0.0 %	59.4 %
45	Indust. 2-shift (16/5) (e.g., comp. air)	Active	62.4 %	4.2 %	31.3 %	2.1 %	95.0 %	95.0 %
46	Indust. 3-shift (24/5) (e.g., comp. air)	Active	44.4 %	22.2 %	22.3 %	11.1 %	95.0 %	95.0 %
47	Indust. 4-shift (24/7) (e.g., comp. air)	Active	31.7 %	34.9 %	15.9 %	17.5 %	95.0 %	95.0 %

Net Savings Factors

Measures

CMPDRYER	Compressed air, Air Dryer

Tracks [Base Track]

6013CUST [is base track]	Cust Equip Rpl
6013PRES [is base track]	Pres Equip Rpl

Persistence

The persistence factor is assumed to be one.

Lifetimes

10 years.

Analysis period is the same as the lifetime.

Measure Cost

The incremental cost for this measure is $750.

O&M Cost Adjustments

There are no operation and maintenance cost adjustments for this measure.

Fossil Fuel Description

There are no fossil-fuel algorithms or default values for this measure.

Incentive Level

The incentive for this measure is $375.

Footnotes

[1] Assumes a cycling dryer with a maximum capacity of 125 cfm servicing a 25 hp compressor running 2 shifts.

[2] Based on an analysis of load profiles from 50 facilities using air compressors 40 hp and below. See “Compressed Air Analysis.xlsx” for source calculations.

[3] Manufacturer’s data suggests that cfm output per compressor hp ranges from 4 to 5. As used in the algorithm, the lower estimate will slightly underestimate savings and is the more conservative approach.

[4] Conversion factor based on a linear regression analysis of the relationship between air compressor full load capacity and non-cycling dryer full load kW assuming that the dryer is sized to accommodate the maximum compressor capacity. See “Compressed Air Analysis.xls” for source calculations.

Air-Entraining Air Nozzles

Measure Number:	I-F-5 b
Portfolio:	EVT TRM Portfolio 2017-10
Status:	Active
Effective Date:	2018/1/1
End Date:	[None]
Program:	Business Energy Services
End Use:	Compressed Air

Update Summary

Measure was reviewed according to the 3-year reliability cycle:

- Updated the average compressor kW/CFM numbers. I incorporated more compressor data to refine the average compressor full load package kW/max CFM estimates which impacted and updated the average compressor kW/CFM numbers. These values were being drawn from a statistically small sample of compressor operating data so I expanded the data set.
- Updated the efficient nozzle CFM from using a deemed default value to sourcing the air flow value directly from the installed equipment. Previously, the savings estimate was using the program minimum air flow requirement of 14 CFM to qualify for this measure as a conservative estimate. Revising this measure to source the efficient air flow from the actually installed equipment will increase the accuracy of the savings estimates.
- Combined the three original excel analysis files into one file, removing the three original and uploading the new/revised workbook. Updated the corresponding footnotes and references accordingly.
- Revised an error in the first note, referring to the percent use assumption. Updated it from 5 seconds to 3 seconds of blow-off per minute of compressor run time to remain consistent with the assumptions made in the algorithm section of 5% use or 3 seconds per 60 seconds of blow-off.

Referenced Documents

- PUCO_TRM_Ohio
- Compressed Air Analysis_v3

Description

Air entraining air nozzles use compressed air to entrain and amplify atmospheric air into a stream, thus increasing pressure with minimal compressed air use. They are used as replacements for stationary air nozzles in a production application, or on handheld guns.

Estimated Measure Impacts

Average Annual MWH Savings per unit	Average number of measures per year	Average annual MWH savings per year
0.98[1]		

Algorithms

Electric Demand Savings

ΔkW	= ΔkWh / HOURS

Symbol Table

Electric Energy Savings

ΔkWh	= $(CFM_b - CFM_e) \times COMP \times HOURS \times \%USE$

Where:

%USE = percent of the compressor total operating hours that the nozzle is in use (5% for 3 seconds of use per minute) [2]

ΔkW = gross customer kW savings for the measure

ΔkWh = gross customer annual kWh savings for the measure

CFM_b = Baseline Nozzle CFM (26 CFM - assumes 1/8” diameter orifice)

CFM_e = Efficient Nozzle CFM (sourced from actually installed equipment)

COMP = Compressor kW/CFM - the average amount of electrical demand in kW required to produce one cubic foot of air at 100 PSI (see Average Compressor kW/CFM Table in the Reference Tables section)

HOURS = compressor total operating hours (see Operating Hours section)

See “Compressed Air Analysis_v3.xlsx” for algorithm details.

Baseline Efficiencies

The baseline equipment is an open copper tube of 1/8” orifice diameter or an inefficient air gun using 26 cfm or more.

High Efficiency

The high efficiency equipment is an air nozzle capable of amplifying the air stream by a factor of 25 using 14 cfm or less.

Operating Hours

Single shift (8/5) – 1,976 hours (7 AM – 3 PM, weekdays, minus some holidays and scheduled down time)

2-shift (16/5) – 3,952 hours (7AM – 11 PM, weekdays, minus some holidays and scheduled down time)

3-shift (24/5) – 5,928 hours (24 hours per day, weekdays, minus some holidays and scheduled down time)

4-shift (24/7) – 8,320 hours (24 hours per day, 7 days a week minus some holidays and scheduled down time)

Load Shapes

Calculated demand impacts (kW) represent diversified kW demand savings over each typical hour that compressed air system is operating. Therefore, for shifts that totally encompass the peak capacity periods, the coincidence factor equals 100%. For shifts that only encompass a portion of the peak capacity period, the coincidence factor represents the portion of the peak capacity period included in the shift hours.

44b Indust. 1-shift (8/5) (e.g., comp. air)
45a Indust. 2-shift (16/5) (e.g., comp. air)
46a Indust. 3-shift (24/5) (e.g., comp. air)
47a Indust. 4-shift (24/7) (e.g., comp. air)

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
44	Indust. 1-shift (8/5) (e.g., comp. air)	Active	66.6 %	0.0 %	33.4 %	0.0 %	0.0 %	59.4 %
45	Indust. 2-shift (16/5) (e.g., comp. air)	Active	62.4 %	4.2 %	31.3 %	2.1 %	95.0 %	95.0 %
46	Indust. 3-shift (24/5) (e.g., comp. air)	Active	44.4 %	22.2 %	22.3 %	11.1 %	95.0 %	95.0 %
47	Indust. 4-shift (24/7) (e.g., comp. air)	Active	31.7 %	34.9 %	15.9 %	17.5 %	95.0 %	95.0 %

Net Savings Factors

Measures

CMPNOZZL	Compressed air, Air Nozzle

Tracks [Base Track]

6013CUST [is base track]	Cust Equip Rpl
6013PRES [is base track]	Pres Equip Rpl

Persistence

The persistence factor is assumed to be one.

Lifetimes

10 years.

Analysis period is the same as the lifetime.

Measure Cost

$14 per air nozzle.[3]

O&M Cost Adjustments

There are no operation and maintenance cost adjustments for this measure.

Fossil Fuel Description

There are no fossil-fuel algorithms or default values for this measure.

Incentive Level

$7 per air nozzle.

Reference Tables

Average Compressor kW/CFM[4]

Compressor Control Type	Average Compressor kW/CFM
Modulating w/ BD	0.31
Load/No Load w/ 1 gal/CFM	0.31
Load/No Load w/ 3 gal/CFM	0.29
Load/No Load w/ 5 gal/CFM	0.28
Variable Speed w/ Unloading	0.22

Footnotes

[1] Assumes three seconds of nozzle operation per minute with a modulating compressor with blowdown running 2 shifts.

[2] Assumes 50% handheld air guns and 50% stationary air nozzles. Manual air guns tend to be used less than stationary air nozzles, and a conservative estimate of 1 second of blow-off per minute of compressor run time is assumed. Stationary air nozzles are commonly more wasteful as they are often mounted on machine tools and can be manually operated resulting in the possibility of a long term open blow situation. An assumption of 3 seconds of blow-off per minute of compressor run time is used.

[3] See “Compressed Air Analysis_v3.xlsx” for incremental cost details.

[4] The average compressor kW/CFM values were calculated using DOE part load curves and load profile data from 50 facilities employing compressors less than or equal to 40 hp. See “Compressed Air Analysis.xlsx” for source calculations and data.

No Loss Condensate Drains

Measure Number: I-F-7 b
Portfolio: EVT TRM Portfolio 2017-10
Status: Active
Effective Date: 2018/1/1
End Date: [None]
Program: Business Energy Services
End Use: Compressed Air

Update Summary

Meausure was reviewed according to the 3-year reliability cycle:

- Ammended the first foot note and the estimated measure impacts to use the same assumptions as the measure defaults of 1/4" diamter orifice for the drain.
- Updated the average compressor kW/CFM numbers. I incorporated more compressor data to refine the average compressor full load package kW/max CFM estimates which impacted and updated the average compressor kW/CFM numbers. These values were being drawn from a statistically small sample of comrpessor operating data so I expanded the data set.
- Combined the three original excel analysis files into one file, removing the three original and uploading the new/revised workbook. Updated the corresponding footnotes and references accordingly.

Referenced Documents

- Compressed Air Analysis

Description

When air is compressed, water in the form of condensation is squeezed out of the compressed air and collects in piping and storage tanks. The water must be drained so as not to interfere with the flow of compressed air and so it will not corrode the piping or tank. Many drains are controlled by a timer and open an orifice for a programmed set amount of time, regardless of the level of the condensate. Thus compressed air is allowed to escape after the condensate has drained. Timed drains typically continue to operate even when the compressor is down, effectively bleeding off useful stored air that must be remade when the compressor is restarted. No Loss Condensate drains are controlled by a sensor and only open when there is a need to drain condensate, and close before compressed air can escape.

Estimated Measure Impacts

Average Annual MWH Savings per unit	Average number of measures per year	Average annual MWH savings per year
2.5[1]		

Algorithms

Electric Demand Savings

ΔkW	= ΔkWh / HOURS

Symbol Table

Electric Energy Savings

ΔkWh	= ALR × COMP × OPEN × AF × PNC

Where:

ΔkW	=	gross customer kW savings for the measure
ΔkWh	=	gross customer annual kWh savings for the measure
AF	=	Adjustment factor to account for the fact that the system may run out of compressed air due to leakage and timed drains when the compressor is down. Savings are only claimed for the average of the compressor hours and the total hours per year (see Adjustment Factors (AF) by Compressor Operating Hours).
ALR	=	Air Loss Rate - an hourly average rate for the timed drain dependent on Drain Orifice Diameter and Pressure, expressed in CFM (see Average Air Loss Rates in the Reference Tables section). The default value, where the actual baseline system is unknown, shall be 100.9 CFM.[2]
COMP	=	Compressor kW/CFM - the average amount of electrical demand in kW required to produce one cubic foot of air at

		100 PSI (see Average Compressor kW/CFM Table in the Reference Tables section)
HOURS	=	compressor total operating hours (see Operating Hours section)
OPEN	=	hours per year the timed drain is open (146 – assuming 10 second drain operation every 10 minutes)[3]
PNC	=	% Not Condensate - percentage of time that compressed air escapes instead of condensate (75% - conservative assumption based on professional judgment)

See "Compressed Air Analysis.xlsx" for algorithm details.

Baseline Efficiencies

The baseline equipment is a timed drain that operates according to a preset schedule regardless of the presence of condensate.

High Efficiency

The high efficiency equipment is a no loss condensate drain controlled by a sensor and only opens when there is a need to drain condensate and closes before any compressed air is vented.

Operating Hours

Single shift (8/5) – 1976 hours (7 AM – 3 PM, weekdays, minus some holidays and scheduled down time)

2-shift (16/5) – 3952 hours (7AM – 11 PM, weekdays, minus some holidays and scheduled down time)

3-shift (24/5) – 5928 hours (24 hours per day, weekdays, minus some holidays and scheduled down time)

4-shift (24/7) – 8320 hours (24 hours per day, 7 days a week minus some holidays and scheduled down time)

Load Shapes

Calculated demand impacts (kW) represent diversified kW demand savings over each typical hour that compressed air system is operating. Therefore, for shifts that totally encompass the peak capacity periods, the coincidence factor equals 100%. For shifts that only encompass a portion of the peak capacity period, the coincidence factor represents the portion of the peak capacity period included in the shift hours.

44b Indust. 1-shift (8/5) (e.g., comp. air)
45a Indust. 2-shift (16/5) (e.g., comp. air)
46a Indust. 3-shift (24/5) (e.g., comp. air)
47a Indust. 4-shift (24/7) (e.g., comp. air)

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
44	Indust. 1-shift (8/5) (e.g., comp. air)	Active	66.6 %	0.0 %	33.4 %	0.0 %	0.0 %	59.4 %
45	Indust. 2-shift (16/5) (e.g., comp. air)	Active	62.4 %	4.2 %	31.3 %	2.1 %	95.0 %	95.0 %
46	Indust. 3-shift (24/5) (e.g., comp. air)	Active	44.4 %	22.2 %	22.3 %	11.1 %	95.0 %	95.0 %
47	Indust. 4-shift (24/7) (e.g., comp. air)	Active	31.7 %	34.9 %	15.9 %	17.5 %	95.0 %	95.0 %

Net Savings Factors

Measures

CMPDRAIN	Compressed Air, No Loss Condensate Drain

Tracks [Base Track]

6013CUST [is base track]	Cust Equip Rpl
6013PRES [is base track]	Pres Equip Rpl

Persistence

The persistence factor is assumed to be one.

Lifetimes

5 years.

Analysis period is the same as the lifetime.

Measure Cost

Assume an incremental cost of $200.[4]

O&M Cost Adjustments

There are no operation and maintenance cost adjustments for this measure.

Fossil Fuel Description

There are no fossil-fuel algorithms or default values for this measure.

Incentive Level

The incentive for this measure is $100 per unit.

Reference Tables

Average Air Loss Rates (CFM)

Pressure (psig)	Orifice Diameter (inches)					
	1/64	1/32	1/16	1/8	1/4	3/8
70	0.29	1.16	4.66	18.62	74.4	167.8
80	0.32	1.26	5.24	20.76	83.1	187.2
90	0.36	1.46	5.72	23.10	92.0	206.6
95	0.38	1.51	6.02	24.16	96.5	216.8
100	0.40	1.55	6.31	25.22	100.9	227.0
105	0.42	1.63	6.58	26.31	105.2	236.7
110	0.43	1.71	6.85	27.39	109.4	246.4
115	0.45	1.78	7.12	28.48	113.7	256.1
120	0.46	1.86	7.39	29.56	117.9	265.8
125	0.48	1.94	7.66	30.65	122.2	275.5

Source: US DOE Compressed Air Tip Sheet #3, August 2004, from Fundamentals for Compressed Air Systems Training offered by the Compressed Air Challenge

Average Compressor kW/CFM[5]

Compressor Control Type	Average Compressor kW/CFM
Modulating w/ BD	0.31
Load/No Load w/ 1 gal/CFM	0.31
Load/No Load w/ 3 gal/CFM	0.29
Load/No Load w/ 5 gal/CFM	0.27
Variable Speed w/ Unloading	0.22

Adjustment Factors (AF) by Compressor Operating Hours

Compressor Operating Hours	AF
Single Shift – 2080 Hours	0.62

2-Shift – 4160 Hours	0.74
3-Shift – 6240 Hours	0.86
4-Shift – 8320 Hours	0.97

Footnotes

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[1] Assumes a baseline of ¼" drain orifice operating 10 seconds per 10 minutes with a modulating compressor with blow down running 2 shifts.

[2] 100.9 CFM based on an orifice size of ¼” and a typical system pressure of 100 psi. Orifice sizes for timed drains found in EVT’s research range from 5/32” to 9/16”, with the most common size being 7/16”; ¼” is considered a reasonably conservative estimate of average size. 100 psi is a conservative estimate of average system pressure; most systems are run at higher pressures than 100 psi.

[3] Based on EVT experience, 10 seconds of drain operation every 10 minutes is a conservative estimate. Many facilities simply use the default timed drain setting or adjust the drain to the highest allowable frequency and duration. Both practices are excessive for most operations.

[4] See “Compressed Air Analysis.xlsx" for incremental cost details.

[5] The average compressor kW/CFM values were calculated using DOE part load curves and load profile data from 50 facilities employing compressors less than or equal to 40 hp. See “Compressed Air Analysis.xls” for source calculations and source data.

Air Receivers for Load/No Load Compressors

Measure Number:	I-F-8 b
Portfolio:	EVT TRM Portfolio 2017-10
Status:	Active
Effective Date:	2018/1/1
End Date:	[None]
Program:	Business Energy Services
End Use:	Compressed Air

Update Summary

Measure was reviewed according to the 3-year reliability cycle:

- Updated the incremental cost. The original cost data was sourced from an online retailer. I went to the same online retailer's website and updated the linear regression cost model in the excel file "Compressed Air Analysis.xlsx" to reflect the retailer's current prices. The multiplier in the incremental cost calculation was updated from 5 to 4.67.
- Combined the three original excel analysis files into one file, removing the three original and uploading the new/revised workbook. Updated the corresponding footnotes and references accordingly.

Referenced Documents

- Compressed Air Analysis

Description

Using an air receiver (a storage tank) will buffer the air demands of the system on the compressor, thus eliminating short cycling. Although a load/no load compressor unloads in response to lowered demand, it does so over a period of time to prevent lubrication oil from foaming. Therefore, reducing the number of cycles reduces the number of transition times from load to no load and saves energy. Savings are calculated using representative baseline and efficient demand numbers for compressor capacities according to the facility's load shape, and the number of hours the compressor runs at that capacity. Demand curves are as per DOE data for load/no load compressors and various gallon per CFM storage ratios.

Estimated Measure Impacts

Average Annual MWH Savings per unit	Average number of measures per year	Average annual MWH savings per year
10.1[1]		

Algorithms

Electric Demand Savings

ΔkW	= ΔkWh / HOURS

Symbol Table

Electric Energy Savings

ΔkWh	$= 0.9 \times hp_{compressor} \times HOURS \times (CF_b - CF_e)$

Where:

ΔkW	=	gross customer kW savings for the measure
ΔkWh	=	gross customer annual kWh savings for the measure
0.9	=	compressor motor nominal hp to full load kW conversion factor[2]
CF_b	=	baseline compressor factor (see "Compressor Factors by Control Type" in Reference Tables section). The default value shall be 0.890, based on a Modulating Compressor with Blow Down.
CF_e	=	efficient compressor factor (see "Compressor Factors by Control Type" in Reference Tables section). The default value shall be 0.812, based on a Load/No Load Compressor with 4 gallons of storgage per cfm.
HOURS	=	compressor total hours of operation (see Operating Hours section)
$hp_{compressor}$	=	compressor motor nominal hp

See “Compressed Air Analysis.xlsx” for algorithm details.

Baseline Efficiencies

The baseline equipment is a load/no load compressor with a 1 gal/cfm storage ratio or a modulating compressor with blow down.

High Efficiency

The high efficiency equipment is a load/no load compressor with a 4 gal/cfm storage ratio or greater.

Operating Hours

Single shift (8/5) – 1976 hours (7 AM – 3 PM, weekdays, minus some holidays and scheduled down time)

2-shift (16/5) – 3952 hours (7AM – 11 PM, weekdays, minus some holidays and scheduled down time)

3-shift (24/5) – 5928 hours (24 hours per day, weekdays, minus some holidays and scheduled down time)

4-shift (24/7) – 8320 hours (24 hours per day, 7 days a week minus some holidays and scheduled down time)

Load Shapes

Calculated demand impacts (kW) represent diversified kW demand savings over each typical hour that compressed air system is operating. Therefore, for shifts that totally encompass the peak capacity periods, the coincidence factor equals 100%. For shifts that only encompass a portion of the peak capacity period, the coincidence factor represents the portion of the peak capacity period included in the shift hours.

44b Indust. 1-shift (8/5) (e.g., comp. air)
45a Indust. 2-shift (16/5) (e.g., comp. air)
46a Indust. 3-shift (24/5) (e.g., comp. air)
47a Indust. 4-shift (24/7) (e.g., comp. air)

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
44	Indust. 1-shift (8/5) (e.g., comp. air)	Active	66.6 %	0.0 %	33.4 %	0.0 %	0.0 %	59.4 %
45	Indust. 2-shift (16/5) (e.g., comp. air)	Active	62.4 %	4.2 %	31.3 %	2.1 %	95.0 %	95.0 %
46	Indust. 3-shift (24/5) (e.g., comp. air)	Active	44.4 %	22.2 %	22.3 %	11.1 %	95.0 %	95.0 %
47	Indust. 4-shift (24/7) (e.g., comp. air)	Active	31.7 %	34.9 %	15.9 %	17.5 %	95.0 %	95.0 %

Net Savings Factors

Measures

CMPRECVR	Compressed air, Air Receiver

Tracks [Base Track]

6013CUST [is base track]	Cust Equip Rpl
6013PRES [is base track]	Pres Equip Rpl

Persistence

The persistence factor is assumed to be one.

Lifetimes

10 years.

Analysis period is the same as the lifetime.

Measure Cost

Incremental Cost ($) = 4.67 x ($TANK_e$ – $TANK_b$)

Where:

4.67[3] = air receiver tank size (gals) to equipment cost conversion factor

$TANK_e$ = efficient tank size (gal)

$TANK_b$ = existing tank size (gal)

O&M Cost Adjustments

There are no operation and maintenance cost adjustments for this measure.

Fossil Fuel Description

There are no fossil-fuel algorithms or default values for this measure.

Incentive Level

The incentive for this measure is half the calculated incremental cost.

Reference Tables

Compressor Factors by Control Type[4]

Control Type	Compressor Factor
Modulating w/ Blow Down	0.890
Load/No Load with 1 gal/CFM storage	0.909
Load/No Load with 3 gal/CFM storage	0.831
Load/No Load with 4 gal/CFM storage	0.812
Load/No Load with 5 gal/CFM storage	0.806

Footnotes

[1] Assumes 25 hp load/no load compressor running 2 shifts going from 1 to 5 gal/cfm storage ratio.

[2] Conversion factor based on a linear regression analysis of the relationship between air compressor motor nominal horsepower and full load kW from power measurements of 72 compressors at 50 facilities on Long Island. See "Compressed Air Analysis.xlsx".

[3] Conversion factor based on a linear regression analysis of the relationship between air receiver storage capacity and incremental cost. See "Compressed Air Analysis.xlsx" for source calculations and costs.

[4] Compressor factors were developed using DOE part load data for different compressor control types as well as load profiles from 50 facilities employing air compressors less than or equal to 40 hp. "See "Compressed Air Analysis.xlsx" for source data and calculations.

Heat Recovery Units for Dairy Farms

Measure Number:	I-K-2 b
Portfolio:	EVT TRM Portfolio 2017-11
Status:	Active
Effective Date:	2018/1/1
End Date:	[None]
Program:	Business Energy Services
End Use:	Hot Water

Update Summary

- Due to the relatively low volume of measures prescriptively implemented, this measure was not opted for a major algorithm overhaul. As the original characterization for this measure aggregated savings and costs over a 9 year period for custom projects from 2003 to 2012, it was decided to incorporate custom projects from 2013 through 2017 to supplement these values.
- Due to a limited effect on the savings estimates, these values were not updated.
- The only revision made was to the incremental cost estimates. The updated costs are an average of 68 custom projects implemented from 2010 through 2017. Subsequent edits were made to the analysis file as well to incorporate the newer project data.

Referenced Documents

- Dairy-HRU-Analysis_v3

Description

A system used in dairy applications that uses waste heat from the compressor of a refrigerated milk cooling system to pre-heat water for either an electric or fossil fuel water heating system.

Estimated Measure Impacts

	Average Annual Savings per unit	Average number of measures per year[1]	Average Annual Savings per year
Heat Recovery Unit (Electric Savings)	6.378 MWH	11	70.16 MWH
Heat Recovery Unit (Fossil Fuel Savings)	52.46 MMBTU	14	734.4 MMBTU

Algorithms

Electric Demand Savings

ΔkW = 4.475 kW

Symbol Table

Electric Energy Savings

ΔkWh = 6,378 kWh

Symbol Table

Fossil Fuel Savings

$\Delta MMBTU$ = 52.46 MMBTU

Where:

ΔkW = gross customer connected load kW savings for the measure

ΔkWh = gross customer average annual kWh savings for the measure

$\Delta MMBTU$ = gross customer average annual MMBTU savings for the measure

Savings estimates are the average savings claimed for EVT custom projects from 2003 through 2012, see Dairy HRU Analysis_v3.xls

Baseline Efficiencies

The baseline reflects no heat recovery from the refrigerator compressor.[2]

High Efficiency

The high efficiency case is installation and use of a heat recovery unit on the refrigerator compressor.

Operating Hours

N/A.

Load Shapes

111a Farm Plate Cooler / Heat Recovery Unit

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
111	Farm Plate Cooler / Heat Recovery Unit	Active	29.0 %	16.4 %	31.6 %	23.1 %	27.0 %	16.1 %

Net Savings Factors

Measures

HWEHRCMP	Heat recovery, compressor

Tracks [Base Track]

6013PRES [is base track]	Pres Equip Rpl
6014PRES [is base track]	6014PRES

Persistence

The persistence factor is assumed to be one.[3]

Lifetimes

10 years.

Measure Cost

Heat Recovery Unit (Electric or Fossil Fuel Savings): $4,353 [4]

O&M Cost Adjustments

There are no standard operation and maintenance cost adjustments used for this measure.

Fossil Fuel Description

There are no fossil-fuel algorithms or default savings when electric savings is claimed for this measure. As the energy savings are associated with the water heater, fossil fuel savings occur if the water heater uses fossil fuel rather than electricity.

Footnotes

[1] Assumes that there will be ~50% more Rx measures per year than the average number of custom measures per year from 2003 through 2011, see AG HRU Analysis.xls

[2] While a heat recovery unit would be baseline for a new construction project, farmers typically re-use old equipment when extensively renovating old facilities. New construction, due to construction of new facilities, is rare and EVT staff has only heard of one case (between 2006 and 2012) where a new construction project resulted in purchase of new equipment.

[3] This equipment has no moving parts or controls and therefore rarely experiences downtime prior to failure due to corrosion at the end of service life.

[4] Value derived from Efficiency Vermont custom data 2010-2017, see Dairy HRU Analysis_v3.xls

Commercial Ventilation Fan

Measure Number:	I-B-5 b
Portfolio:	EVT TRM Portfolio 2017-07
Status:	Active
Effective Date:	2018/1/1
End Date:	[None]
Program:	Business Energy Services
End Use:	HVAC

Update Summary

This is a reliability update that includes a change of high efficiency levels (CFM/watt) based on custom projects that have been performed over the past 4 years. This analysis follows the previous methodology, which reveiwed custom projects from 2009-2012.

Referenced Documents

- measure_life_GDS[1]
- evt-commercial-ventilation-fan-analysis-july-2017-xlsx

Description

An ENERGY STAR qualified efficient fan configured to meet ASHRAE 62.1 requirements for bathroom ventilation. This market opportunity is defined by the need for continuous mechanical ventilation in bathrooms and mechanical closets of small commercial and industrial buildings during operating hours. This measure assumes an efficient fan will be run during business hours to provide 10-500 CFM under static pressure conditions ranging from 0.1 to 0.25 inches of water.

Algorithms

Electric Demand Savings

$\Delta kW = CFM \times (1 / Fan_{Efficiency,\ Baseline} - 1 / Fan_{Efficiency,\ Efficient}) / 1000$

Symbol Table

Electric Energy Savings

$\Delta kWh = Hours \times \Delta kW$

Where:

ΔkW = connected load kW savings per qualified ventilation fan and controls

Demand Savings

CFM code	Nominal CFM Range	Assumed CFM	ΔkW
CFM1	10-89	70	0.029
CFM2	90-150	110	0.046
CFM3	151-250	175	0.073
CFM4	251-500	350	0.145

ΔkWh = Energy Savings

CFM code	Nominal CFM Range	Assumed CFM	ΔkWh
CFM1	10-89	70	85
CFM2	90-150	110	133
CFM3	151-250	175	212
CFM4	251-500	350	424

CFM = Nominal Capacity of the exhaust fan. Savings calculatation use a common rating within the range, as shown in the “Assumed CFM” column

$Fan_{Efficiency,\ Baseline}$ = Efficacy for baseline fan[1]

1.7 CFM/Watt

$Fan_{Efficiency,\ Efficient}$ = Efficacy for efficient fan[2]

6.1 CFM/Watt

Hours = assumed annual run hours

2920[3]

Baseline Efficiencies

New standard efficiency exhaust-only ventilation fan operating in accordance with recommended ventilation rate indicated by ASHRAE 62.1 for commercial bathrooms during business hours.

High Efficiency

New efficient exhaust-only ventilation fan, operating in accordance with recommended ventilation rate indicated by ASHRAE 62.1 for commercial bathrooms during business hours.

Operating Hours

2870[3]

Load Shapes

113a Commercial Small Exhaust-only Vent Fan

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
113	Commercial Small Exhaust-only Vent Fan	Active	48.8 %	19.5 %	22.2 %	9.5 %	50.8 %	72.4 %

Net Savings Factors

Measures

VNTXCEIL	Exhaust fan, ceiling
VNTXVFAN	Exhaust fan, variable speed

Tracks [Base Track]

6012CNIR [is base track]	C&I Retro
6013CUST [is base track]	Cust Equip Rpl
6013PRES [is base track]	Pres Equip Rpl
6014PRES [is base track]	6014PRES
6014CUST [is base track]	6014CUST

Persistence

The persistence factor is assumed to be one.

Lifetimes

15 years[4]. Analysis period is the same as the lifetime.

Measure Cost

Incremental cost per installed fan is $110 for quiet, efficient fans[5].

O&M Cost Adjustments

There are no O&M Cost Adjustments for this measure.

Fossil Fuel Description

There are no fossil fuel savings for this measure.

Footnotes

[1] Weighted average of 20 best-selling ceiling exhaust fans at Grainger on 6/26/2017 using assumed sales distribution, 2017 Base-Efficacy sheet

	of EVT_Commercial Ventilation Fan_Analysis_June 2017.xlsx
[2]	Average of fans installed through EVT custom projects 2012-2016, 2017 EE-Efficacy sheet of EVT_Commercial Ventilation Fan_Analysis_June 2017.xlsx
[3]	Median of run hours of fans installed through EVT custom projects 2008-2011, Cell C67 on 2017 EE-Efficacy tab of EVT_Commercial Ventilation Fan_Analysis_June 2017.xlsx.
[4]	Estimate based upon GDS Associates Measure Life Report "Residential and C&I Lighting and HVAC measures" 25 years for residential whole-house fans, 19 for residential thermostatically-controlled attic fans, and 15 years for several commercial measures.
[5]	Based on historical incremental costs from EVT custom project data (2012-2016). Refer to Cell H59 on 2017 EE-Efficacy tab of EVT_Commercial Ventilation Fan_Analysis_June 2017.xlsx.

Package Terminal Heat Pump (Hotel Room)

Measure Number:	I-B-6 a
Portfolio:	83
Status:	Active
Effective Date:	2013/1/1
End Date:	[None]
Program:	Business Energy Services
End Use:	HVAC

Referenced Documents

- PTHP_Analysis.xlsx
- State Screening Tool for PTHP
- Massachusetts Electric PAs Cross-Cutting C&I Free-ridership and Spillover Field Study
- 2011 Commercial and Industrial Electric and Natural Gas Programs FR/SO Study

Description

A 9,000 BTU/hour package terminal heat pump (PTHP) is purchased instead of a package terminal air conditioner (PTAC) with electric resistance heat and installed in a hotel room, as an end of life replacement of an existing unit.

This program will be targeted exclusively to hotels and motels likely to have existing PTAC units with electric resistance heat. While there may be application for PTHP equipment in the context of new construction, the baseline is difficult to generalize. Therefore new construction applications will be handled through a custom process.

Algorithms

Electric Demand Savings

ΔkW = 0.697 kW

Symbol Table

Electric Energy Savings

ΔkWh = 1,443 kWh

Where:

ΔkW = gross customer connected load kW savings for the measure

ΔkWh = gross customer average annual kWh savings for the measure

PTHP Savings[1]

Baseline Efficiencies

The baseline reflects a code compliant PTAC with resistance heat.[2]

High Efficiency

The high efficiency case matches standards specified in the 2011 Energy Star scoping report. [3]

Operating Hours

765 Cooling[4]

1,305 Heating

Load Shapes

114a PTHP, Hotel

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
114	PTHP, Hotel	Active	40.0 %	48.9 %	5.4 %	5.7 %	34.2 %	41.6 %

Net Savings Factors

Measures

ACEHPPTL	Package terminal heat hump

Tracks [Base Track]

6012CNIR [is base track]	C&I Retro

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
C&I Retro	6012CNIR	ACEHPPTL	0.89	1.00

Persistence

The persistence factor is assumed to be one.

Lifetimes

15 years

Measure Cost

$130[5]

O&M Cost Adjustments

There are no standard operation and maintenance cost adjustments used for this measure.

Fossil Fuel Description

There are no fossil-fuel algorithms or default savings for this measure.

Footnotes

[1] Savings estimate is based on 9,000 BTU/hr unit, see calculation tool in reference documents

[2] 2011 Vermont Commercial Building Energy Standards, see Table 503.2.3(3)

[3] Energy Star Market and Industry Scoping Report, Dec 2011 (table 6, *http://www.energystar.gov/ia/products/downloads/ESTAR_PTAC_and_PTHP_Scoping_Report_Final_Dec_2011.pdf*)

[4] Assumes balance point of 55 degrees and that equipment is oversized by 25% on average

[5] Values derived from review of catalogues commonly used by hotel managers.

Advanced Thermostats

Measure Number:	I-D-1 a
Portfolio:	EVT TRM Portfolio 2018-08
Status:	Inactive
Effective Date:	2018/1/1
End Date:	2018/12/31
Program:	Business Energy Services
End Use:	HVAC

Update Summary

New measure to characterize savings for advanced thermostats installed in small and medium business applications.

Draws savings estimates from Existing Homes/RNC characterization in the absence of commercial specific evaluations. This characterization will be adjusted once data is collected on SMB applications.

Referenced Documents

- VT CI Existing Buildings Market Assessment and Characterization_2012-10-6_FINAL
- VT CI New Construction Market Assessment and Characterization__FINAL_2012-12-21
- IL SAG Smart Thermostat Preliminary Gas Impact Findings 2015-12-08 to IL SAG
- Studies informing the TRM Savings Characterization for Advanced Thermostats
- VGS Usage Regression Work_04182017
- 2016 Vermont Business Sector Market Characterization and Assessment Study
- Programmable Thermostats Furnace Fan Analysis
- SMB-Advanced Thermostat
- LoadProfileAverager2010_SMBAdvThermostats

Description

This measure characterizes the energy savings from the installation of a new thermostat(s) in a small to medium business location, to reduce heating and cooling consumption through a configurable schedule of temperature set-points (like a programmable thermostat) *and* automatic variations to that schedule to better match HVAC system runtimes to meet occupant comfort needs. These schedules may be defaults, established through user interaction, and be changed manually at the device or remotely through a web or mobile app. Automatic variations to that schedule could be driven by local sensors and software algorithms, and/or through connectivity to an internet software service. Data triggers to automatic schedule changes might include, for example: occupancy/activity detection, arrival & departure of conditioned spaces, optimization based on historical or population-specific trends, weather data and forecasts.[1] This class of products and services are relatively new, diverse, and rapidly changing. Generally, the savings expected for this measure aren't yet established at the level of individual features, but rather at the system level and how it performs overall. Note that it is a very active area of ongoing study to better map features to savings value, and establish standards of performance measurement based on field data so that a standard of efficiency can be developed. That work is not yet complete but does inform the treatment of some aspects of this characterization and recommendations.

The measure assumes that the advanced thermostat is controlling a portion of the buildings heating/cooling load and, in the absence of small business specific assumptions, is assumed to control a similar load as Residential applications. This will be revised as data is collected on this small business application. Efficiency Vermont will track and provide incentives for up to six advanced thermostats per commercial building.

The thermostat must be installed and connected with the manufacturer in order to be eligible for a rebate.

Baseline Efficiencies

The baseline mix of programmable v manual thermostats for small to medium business customers is 89% manual and 11% programmable for existing buildings[2].

For New Construction, the baseline is a programmable thermostat due to code requirements.

Efficient Equipment

The criteria for this measure are established by replacement of a manual-only or programmable thermostat, with one that has the default enabled capability—or the capability to automatically—establish a schedule of temperature setpoints according to driving device inputs above and beyond basic time and temperature data of conventional programmable thermostats. As summarized in the description, this category of products and services is broad and rapidly advancing in regards to their capability, usability, and sophistication, but at a minimum must be capable of two-way communication[3] and exceed the typical performance of manual and conventional programmable thermostats through the automatic or default capabilities described above.

Algorithms

Electric Demand Savings

ΔkW	$= \text{Max}(\Delta kWh_{heating} / EFLH_{heat} , \Delta kWh_{cooling} / EFLH_{cool})$

Symbol Table

Electric Energy Savings

ΔkWh	$= \Delta kWh_{heating} + \Delta kWh_{cooling}$
$\Delta kWh_{heating}$	$= \%ElectricHeat \times Elec\_Heating\_Consumption \times \%Controlled \times Heating\_Reduction + (\Delta MMBtu \times F_e \times 293)$
$\Delta kWh_{cooling}$	$= \%AC \times ((EFLH_{cool} \times Capacity \times 1/SEER)/1000) \times Cooling\_Reduction$

Symbol Table

Fossil Fuel Savings

$\Delta MMBtu$	$= \Sigma\ (\%FossilHeat \times Heating\_Consumption \times \%Controlled) \times Heating\_Reduction$

Where:

%AC = Fraction of customers with central air-conditioning

Central air conditioning?	%AC
Yes	100%
No	0%
Unknown	56%[6]

%Controlled = Assumed percentage of total heating load being controlled by thermostat.

= 69% for Existing Buildings and 53% for NC[7]

%ElectricHeat = Percentage of heating savings assumed to be electric

Heating fuel	%ElectricHeat	
	Existing Buildings[8]	New Construction[9]
Electric	100%	
Fossil Fuel	0%	
Unknown	25%	61%

%FossilHeat = Percentage of heating savings assumed to be fossil fuel (note for the 'unknown' category natural gas is not included as it will be known that it is not natural gas)

Heating fuel		%FossilHeat	
		Existing Buildings[8]	New Construction[9]
Electric		0%	
Fossil Fuel		100%	
Unknown	Oil	27%	0%
	Propane	48%	39%

ΔkW = Annual demand reduction.

$\Delta kWh_{cooling}$ = Electric savings from cooling energy usage reductions

$\Delta kWh_{heating}$ = Electric savings from heating energy usage reductions. This accounts for both electric heat (heat pumps) and fan/pump savings in the case of a fossil heating system.

ΔkWh = Electrical savings are a function of both heating and cooling energy usage reductions.

$\Delta MMBtu$ = Fuel savings if fossil fuel heating system

293 = kWh per MMBtu

Capacity = Capacity of AC unit. (Note: One refrigeration ton is equal to 12,000 Btu/hr.)

= 41,400 Btuh/hr[10]

Cooling_Reduction = Assumed percentage reduction in total cooling energy consumption due to installation of advanced thermostat

= 8.0%[11]

$EFLH_{cool}$ = Estimate of annual full load cooling hours for air conditioning equipment.

= 755[4]

$EFLH_{heat}$ = Assumed Equivalent Full Load Hours for heating

= 1062[5]

Elec_Heating_Consumption = Estimate of annual heating consumption for heat pump heated buildings:

Elec_Heating_Consumption (kWh)	
Existing Buildings	**New Construction**
8,273[12]	6,416[13]

F_e = Furnace fan / boiler pump energy consumption as a percentage of annual fuel consumption

= 3.14%[14]

Heating_Consumption = Estimate of annual heating consumption

	Gas_Heating_Consumption (MMBtu)	
	Existing Buildings[17]	**New Construction[18]**
Gas	81	67
Oil	84	70
Unknown	82	67

Heating_Reduction = Assumed percentage reduction in total heating energy consumption due to advanced thermostat

Program	**Existing Thermostat Type**	**Heating_Reduction[15]**
Existing Buildings	Unknown (Blended)	8.0%
New Construction	Programmable	5.6%

SEER = The cooling equipment's Seasonal Energy Efficiency Ratio rating (kBtu/kWh)

SEER	
Existing Buildings	**New Construction**
11.7[16]	20.2[16]

Load Shapes

17a Commercial Space heat
125a SMB Advanced Thermostat - Electric Heat & Cooling
124b SMB Advanced Thermostat - Fossil Heat & Cooling
126b SMB Advanced Thermostat - Unknown Heat & Cooling

Number	**Name**	**Status**	**Winter On kWh**	**Winter Off kWh**	**Summer On kWh**	**Summer Off kWh**	**Winter kW**	**Summer kW**
17	Commercial Space heat	Active	38.7 %	61.2 %	0.0 %	0.1 %	57.0 %	0.3 %
125	SMB Advanced Thermostat - Electric Heat & Cooling	Active	31.7 %	42.5 %	19.9 %	5.9 %	58.1 %	53.5 %
124	SMB Advanced Thermostat - Fossil Heat & Cooling	Active	19.0 %	8.8 %	55.8 %	16.4 %	6.6 %	80.8 %
126	SMB Advanced Thermostat - Unknown Heat & Cooling	Active	28.3 %	33.4 %	29.6 %	8.7 %	46.8 %	81.0 %

Net Savings Factors

Measures

SHESMART	Advanced Thermostats

Tracks [Base Track]

6013PRES [is base track]	Pres Equip Rpl
6014PRES [is base track]	6014PRES

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Pres Equip Rpl	6013PRES	SHESMART	1.00	1.00
6014PRES	6014PRES	SHESMART	0.95	1.05

Lifetimes

The expected measure life for advanced thermostats is assumed to be similar to that of a programmable thermostat 10 years[19] based upon equipment life only.

Measure Cost

For DI and other programs for which installation services are provided, the actual material, labor, and other costs should be used, with a default of $265 ($225 for the thermostat and $40 for labor). For other program types the average incremental cost for the new installation measure is assumed to be $175[20].

For new construction, the incremental cost between a programmable and advanced thermostat is assumed to be $150[21].

Prescriptive Savings Tables

Deemed savings are provided below[22].

Savings Type	Fuel	Existing Buildings							
		Natural Gas Heat, Cooling	Natural Gas Heat, No Cooling	Oil Heat, Cooling	Oil Heat, No Cooling	LP Heat, Cooling	LP Heat, No Cooling	HP Heat, Cooling	Unknown Heat (not NG), Unknown Cooling
Item Code		ADVSTATSMBE1	ADVSTATSMBE2	ADVSTATSMBE3	ADVSTATSMBE4	ADVSTATSMBE5	ADVSTATSMBE6	ADVSTATSMBE7	ADVSTATSMBE8
Heating	Natural Gas (MMBTU)	4.5	4.5	0.0	0.0	0.0	0.0	0.0	0.0
Heating	Oil (MMBTU)	0.0	0.0	4.6	4.6	0.0	0.0	0.0	1.3
Heating	LP (MMBTU)	0.0	0.0	0.0	0.0	4.5	4.5	0.0	2.1
Heating	Electric (kWh)	41	41	43	43	41	41	457	145
Cooling	Electric (kWh)	214	0.0	214	0.0	214	0.0	214	120
	Total MMBTU	4.5	4.5	4.6	4.6	4.5	4.5	0.0	3.4
	Total kWh	255	41	257	43	255	41	670	265
	kW	0.2831	0.0390	0.2831	0.0404	0.2831	0.0390	0.4300	0.1585
	Loadshape Used	120b Advanced Thermostat - Fossil Heat & Cooling	17a Commercial Space heat	120b Advanced Thermostat - Fossil Heat & Cooling	17a Commercial Space heat	120b Advanced Thermostat - Fossil Heat & Cooling	17a Commercial Space heat	121b Advanced Thermostat - Electric Heat & Cooling	122b Advanced Thermostat - Unknown Heat & Cooling

Savings Type	Fuel	New Buildings							
		Natural Gas Heat, Cooling	Natural Gas Heat, No Cooling	Oil Heat, Cooling	Oil Heat, No Cooling	LP Heat, Cooling	LP Heat, No Cooling	HP Heat, Cooling	Unknown Heat (not NG), Unknown Cooling
Item Code		ADVSTATSMBN1	ADVSTATSMBN2	ADVSTATSMBN3	ADVSTATSMBN4	ADVSTATSMBN5	ADVSTATSMBN6	ADVSTATSMBN7	ADVSTATSMBN8
Heating	Natural Gas (MMBTU)	2.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0
Heating	Oil	0.0	0.0	2.1	2.1	0.0	0.0	0.0	0.0

Heating	(MMBTU)	0.0	0.0	2.1	2.1	0.0	0.0	0.0	0.0
Heating	LP (MMBTU)	0.0	0.0	0.0	0.0	2.0	2.0	0.0	0.8
Heating	Electric (kWh)	19	19	20	20	19	19	190	123
Cooling	Electric (kWh)	124	0.0	124	0.0	124	0.0	124	69
	Total MMBTU	2.0	2.0	2.1	2.1	2.0	2.0	0.0	0.8
	Total kWh	143	19	144	19	143	19	314	193
	kW	0.1640	0.0178	0.1640	0.0186	0.1640	0.0178	0.1793	0.1161
	Loadshape Used	120b Advanced Thermostat - Fossil Heat & Cooling	17a Commercial Space heat	120b Advanced Thermostat - Fossil Heat & Cooling	17a Commercial Space heat	120b Advanced Thermostat - Fossil Heat & Cooling	17a Commercial Space heat	121b Advanced Thermostat - Electric Heat & Cooling	122b Advanced Thermostat - Unknown Heat & Cooling

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Footnotes

[1] For example, the capabilities of products and added services that use ultrasound, infrared, or geofencing sensor systems, automatically develop individual models of home's thermal properties through user interaction, and optimize system operation based on equipment type and performance traits based on weather forecasts demonstrate the type of automatic schedule change functionality that apply to this measure characterization.

[2] Based on findings for Office building type from 'Figure 63: Saturation of HVAC System Control Types by Facility Type' from the 2016 VT Business Sector Market Characterization and Assessment Study, April 30 201. Note EMS (Energy Management Systems) were found in 25% of the Offices. It is assumed that these would not be installing Advanced Thermostats and so are not included in the baseline mix.

[3] This measure recognizes that field data may be available, through this 2-way communication capability, to better inform characterization of efficiency criteria and savings calculations. Efficiency Vermont will be exploring ways to better utilize this data once the program is underway and once the ENERGY STAR specification and program process is finalized.

[4] EFLH for commercial air conditioning are derived directly from the following KEMA report. KEMA, "C&I Unitary HVAC Load Shape Project Final Report", Northeast Energy Efficiency Partnerships, Regional Evaluation, Measurement, and Verification Forum, August 2, 2011. Pg. 57, Table 3-1.

[5] Commercial FLH is a weighted average of commercial FLH values from New York Joint Utiliites,"New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs (Version 4)," April 29, 2016 and Vermont building data provided by Cadmus. See file EVT_Commercial EFLH_Analysis_July 2017 for calculation details.

[6] Value is for Office Building Type as representative of small and medium business customer likely to participate, from Business Sector Market Assessment and Baseline Study: Existing Commercial Buildings, Vol. 1, Final Report, prepared by KEMA for the Department of Public Service, July 10, 2009, Table 5-9

[7] Consistent with Residential assumptions; Based on review of # of thermostats per home data from Vermont Single-Family Existing Homes Onsite Report, 2/15/2013 and Vermont Residential New Construction Baseline Study Analysis of On-Site Audits, 2/13/2013. See 'Advanced Thermostat Analysis_04182017_FINAL.xls'

[8] Unknown values are based upon data for Efficiency Vermont from 'Figure 46 Heating System Fuel Type by EEU' from 2016 VT Business Sector Market Characterization and Assessment Study, April 30 2017. Percentage for electricity is reduced to only include heat pump systems as resistance heat will not be controlled by an Advanced Thermostat (heat pump percentage is based on values for non-VT gas from 'Figure 47 Distribution of Heating System Types by Facility Size and VT Gas Territory' from the same study). Note that the unknown values do not include natural gas as this will be known.

[9] Unknown values are based upon data for Efficiency Vermont from 'Figure 128 Heating System Fuel Type by EEU' from 2016 VT Business Sector Market Characterization and Assessment Study, April 30 2017. Percentage for electricity is reduced to only include heat pump systems as resistance heat will not be controlled by an Advanced Thermostat (heat pump percentage is based on values for non-VT gas from 'Figure 129 Distribution of Heating System Types by Facility Size and VT Gas Territory' from the same study). Note that the unknown values do not include natural gas as this will be known.

[10] Consistent with Residential assumptions: TAG Agreement 2017.

[11] Consistent with Residential assumptions; This assumption is based upon the review of many evaluations from other regions in the US (see "Studies informing the TRM Savings Characterization for Advanced Thermostats.docx"). These sources, are from different regions, products, and program delivery designs, but collectively form a sound basis, and directional guidance for the existence and magnitude of cooling savings. Because cooling savings are more volatile than those for heating due to variables in control behaviors, population, and product factors, conservatism is warranted and 8% is considered a conservative estimate based upon the array of results from these studies. Further evaluation and regular review of this key assumption is encouraged.

[12] Consistent with Residential assumptions; Estimate is based upon calculation of average heating load from Vermont Single-Family Existing Homes Onsite Report, 2/15/2013. This is converted to kWh using relative efficiencies, and an assumption that 90% of heat pump load is delivered in heat pump mode v resistance. See "Advanced Thermostat Analysis_04182017_FINAL.xlsx", for details.

[13] Consistent with Residential assumptions; Estimate is based upon calculation of average heating load from Vermont Residential New Construction Baseline Study Analysis of On-Site Audits, 2/13/2013. This is converted to kWh using relative efficiencies, and an assumption that 90% of heat pump load is delivered in heat pump mode v resistance. See "Advanced Thermostat Analysis_04182017_FINAL.xlsx", for details.

[14] F_e is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (Ef in MMBTU/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the Energy Star version 3 criteria for 2% F_e. See "Programmable Thermostats Furnace Fan Analysis.xlsx" for reference. Note this is a reasonable estimate for a boilers electric consumption which is a similar level to furnaces as per Table 10.1, page 30 of James Lutz et al., Lawrence Berkeley Laboratory "Modeling energy consumption of residential furnaces and boilers in US homes"

(http://eetd.lbl.gov/sites/all/files/modeling_energy_consumption_of_residential_furnaces_and_boilers_in_us_homes_lbnl-53924.pdf).

[15] Savings of 8.8% for manual, and 5.6% for programmable thermostats are taken from Navigant's PowerPoint on Impact Analysis from Preliminary Gas savings findings (slide 28 of 'IL SAG Smart Thermostat Preliminary Gas Impact Findings 2015-12-08 to IL SAG.ppt'). These values are used as the basis for the weighted average savings value for existing buildings. The weighting of manual to programmable thermostats for when unknown is based upon Office building type from 'Figure 63 Saturation of HVAC System Control Types by Facility Type' of 2016 VT Business Sector Market Characterization and Assessment Study, April 30 2017. Note EMS (Energy Management Systems) were found in 25% of the Offices. It is assumed that these would not be installing Advanced Thermostats and so are not included in the baseline mix.

[16] SEER assumption for existing buildings is based on 'Table 16 Cooling Efficiency of Single-Zone Unitary HVAC Systems <5.5 tons' and for new construction 'Table 56 Cooling Efficiency of Single-Zone Unitary HVAC systems' from 2016 VT Business Sector Market Characterization and Assessment Study, April 30 2017.

[17] Consistent with Residential assumptions; Estimate is based upon calculation of average heating load; (FLH * Capacity/1,000,000)/AFUE. FLH and Capacity are based upon natural gas billing data anaylsis provided by Vermont Gas Systems (VGS) (see 'VGS Usage Regression Work_04182017.xls'). AFUE assumptions are from Vermont Single-Family Existing Homes Onsite Report, 2/15/2013. Note the FLH calculation attempts to isolate heating only consumption (removing DHW and other loads). For calculation of savings see "Advanced Thermostat Analysis_04182017_FINAL.xlsx", for details.

[18] Consistent with Residential assumptions; Estimate is based upon calculation of average heating load; (FLH * Capacity/1,000,000)/AFUE. FLH and Capacity are based upon natural gas billing data anaylsis provided by Vermont Gas Systems (VGS) (see 'VGS Usage Regression Work_04182017.xls'). AFUE assumptions are from Vermont Residential New Construction Baseline Study Analysis of On-Site Audits, 2/13/2013. Note the FLH calculation attempts to isolate heating only consumption (removing DHW and other loads). For calculation of savings see "Advanced Thermostat Analysis_04182017_FINAL.xlsx", for details.

[19] Table 1, HVAC Controls, Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, 2007

[20] Market prices vary considerably in this category, generally increasing with thermostat capability and sophistication. The core suite of functions required by this measure's eligibility criteria are available on units readily available in the market roughly in the range of $200 and $250, excluding the availability of any wholesale or volume discounts. The assumed incremental cost is based on the middle of this range ($225) minus a cost of $50 for the baseline equipment blend of manual and programmable thermostats. Note that any add-on energy service costs, which may include one-time setup and/or annual per device costs are not included in this assumption.

[21] Assumed to be $225 minus $75 for programmable thermostat.

[22] See 'SMB Advanced Thermostat.xls' for calculations.

SMARTLIGHT Lighting Distributor Incentives

Measure Number:	I-C-21 i
Portfolio:	EVT TRM Portfolio 2018-10
Status:	Inactive
Effective Date:	2018/1/1
End Date:	2018/12/31
Program:	Business Energy Services
End Use:	Lighting

Update Summary

The following revisions have been made to the measure:

- Updated to use Loadshape #101 for commercial lighting
- Removed reference to separate cooling loadshape
- Added a footnote to show the basis of the new loadshape
- Added residential hours of use
- Added track 6032UPST

Referenced Documents

- PIP #67a: Upstream Distributor Incentive Model
- Calculating Lighting and HVAC Interactions_ASHRAE
- Lighting Efficiency Waste Heat Adjustment Methodology
- NMR Group, Inc., "Northeast Residential Lighting Hours-of-Use Study," prepared for CT Energy Efficiency Board, Cape Light Compact, Massachusetts Energy Efficiency Advisory Council, National Grid MA, National Grid RI, NYSERDA, Northeast Utilities, May 5, 2
- UMPChapter21-residential-lighting-evaluation-protocol
- SMARTLIGHT Reference Tables December2016
- NMR_Efficiency-Maine-Retail-Lighting-Program-Evaluation-Report-2015
- NMR_R154 - CT LED Lighting Study_Final Report_1
- PNNL_Analysis of Daylighting Requirements_Aug 2013
- NEEP_CI Lighting Loadshape_Jul 2011
- EVT Lighting WHF Research_Prescriptive

Description

In reference to PIP #67a: Upstream Distributor Incentive Model, Efficiency Vermont will offer "upstream" incentives to Vermont Electrical Distributors for certain eligible energy-efficient commercial replacement lamps. The eligible technologies are Screw Base LED Lamps, Reduced-Wattage T8 and T5 Lamps, and LED Linear Replacement Lamps. Both replacements and new installations are eligible. See PIP #67a (updated 5/1/2012) for a further discussion of eligible technologies and program procedures. Refer to the ENERGY STAR Integrated Screw Based SSL (LED) Lamps measure for Screw Base LED Lamp savings.

Algorithms

Electric Demand Savings

$$\Delta kW = ((Watts_{BASE} - Watts_{EE}) / 1000) \times ISR \times WHF_d$$

Symbol Table

Electric Energy Savings

$$\Delta kWh = ((Watts_{BASE} - Watts_{EE}) / 1000) \times HOURS \times ISR \times WHF_e$$

Symbol Table

Heating Increased Usage

Oil heating is assumed typical for commercial buildings.

$$\Delta MMBTU_{WH} = (\Delta kWh / WHF_e) \times 0.003412 \times (1 - OA) \times AR \times HF \times DFH / \eta Heat$$

Symbol Table

Waste Heat Adjustment

Cooling savings are incorporated into the electric savings algorithm with the waste heat factor (WHF). See above.

Where:

ΔkW = Gross customer connected load kW savings for the measure

ΔkWh = Gross customer annual kWh savings for the measure

$\Delta MMBTU_{WH}$ = Gross customer annual heating MMBTU fuel increased usage for the measure from the reduction in lighting heat.

$\eta Heat$ = Average heating system efficiency, For prescriptive lighting, assumed to be 79% in existing buildings and 83 % in new construction.[5]

0.003412 = Conversion from kWh to MMBTU

AR = Typical aspect ratio factor. The ASHRAE heating factor applies to perimeter zone heat, therefore it must be adjusted to account for lighting in core zones. It is assumed that 60%[6] is the typical square footage of commercial buildings within 15 feet of exterior wall.

DFH = Percent of lighting in heated spaces. For prescriptive lighting, assumed to be 95%

HF = ASHRAE heating factor of 0.39 for lighting waste heat for Burlington, Vermont.[7] Assumed to be 0.0 for residential lighting.

HOURS = Annual lighting hours of use per year. See table below.

Lamp Category	Operating Hours[4]
Reduced Wattage T8	3,000
Reduced Wattage T5	3,250
LED Linear Replacement - Commercial	3,555
LED Linear Replacement - Residential	986

ISR = In service rate, or the percentage of units rebated that actually get used. See table below.

Measure Group	ISR
Reduced Wattage T8	0.9[1]
Reduced Wattage T5	
LED Linear Replacement	0.97[2]

OA = Outside Air - the average percent of the supply air that is Outside Air, assumed to be 25%.[8]

$Watts_{BASE}$ = Baseline connected Watts from table located in Reference Tables Section.

$Watts_{EE}$ = Energy efficient connected Watts from table located in Reference Tables Section.

WHF_d = Waste heat factor for demand to account for cooling savings from efficient lighting. For prescriptive commercial lighting in existing buildings, the default value is 1.102.[3] The cooling savings are only added to the summer peak savings. The value for Residential lighting is assumed to be 1.0.

WHF_e = Waste heat factor for energy to account for cooling savings from efficient lighting. For prescriptive commercial lighting in existing buildings, the default value is 1.036.[3] The value for Residential lighting is assumed to be 1.0.

Baseline Efficiencies

New or Replacement:

Refer to the "New and Baseline Assumptions" tables in the Reference Tables section for lighting baseline efficiencies and savings.

High Efficiency

Refer to the “New and Baseline Assumptions” tables in the Reference Tables section for efficient lighting wattage and savings.

Load Shapes

Residential: Loadshape #1: Residential Indoor Lighting

Commercial: Loadshape #101: Commercial EP Lighting with Cooling Bonus [9]

1a Residential Indoor Lighting
101c Commercial EP Lighting with cooling bonus

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
1	Residential Indoor Lighting	Active	36.9 %	35.0 %	13.0 %	15.1 %	29.8 %	8.2 %
101	Commercial EP Lighting with cooling bonus	Active	47.7 %	19.2 %	23.0 %	10.1 %	33.8 %	68.1 %

Net Savings Factors

Measures

LBLRWLT8	Reduced-Wattage T8 Lamp
LBLRWLT5	Reduced-Wattage T5 Lamp
LBLT8LED	LED Linear Replacement

Tracks [Base Track]

6013UPST [is base track]	Upstream - Commercial
6032UPST [6032EPEP]	Upstream - Residential

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Upstream - Commercial	6013UPST	LBLRWLT8	0.90	1.00
Upstream - Commercial	6013UPST	LBLRWLT5	0.90	1.00
Upstream - Commercial	6013UPST	LBLT8LED	0.90	1.00

Persistence

The persistence factor is assumed to be one.

Lifetimes

Lifetime is the life of the product, at the reported operating hours (lamp life in hours divided by operating hours per year). Refer to the "Component Costs and Lifetimes" tables in the Reference Tables section for lamp life assumptions. The analysis period is the same as the lifetime, capped at 15 years.

Measure Cost

Refer to "New and Baseline Assumptions" tables in the Reference Tables section for measure costs.

O&M Cost Adjustments

Refer to the "Component Costs and Lifetimes" tables in the Reference Tables section for O&M cost adjustments.

Fossil Fuel Description

See algorithm in 'Heating Increased Usage'

Water Descriptions

There are no water algorithms or default values for this measure.

Reference Tables

See SMARTLIGHT Reference Tables December2016.xlsx for analysis and references.

T8 LED Replacement Lamps (TLED) New and Baseline Assumptions									
EE Measure Description	**EE Cost**	**System WattsEE**	**Baseline Description**	**Base Cost**	**System Watts Base**	**Measure Cost**	**WattsSAVE**	**Measure Code**	**Default Loadshape Description**
T8 LED Replacement Lamp (TLED), < 1200 lumens	$17.75	8.9	F17T8 Standard Lamp - 2 foot	$4.49	15	$13.26	6.1	LBLT8LED	Commercial: Commercial EP Lighting with Cooling Bonus Residential: Residential Indoor Lighting
T8 LED Replacement Lamp (TLED), 1200-2400 lumens	$18.00	15.8	F32T8 Standard Lamp - 4 foot	$3.00	28	$15.00	12.4	LBLT8LED	
T8 LED Replacement Lamp (TLED), > 2400 lumens	$24.25	22.9	F32T8/HO Standard Lamp - 4 foot	$11.00	42	$13.25	18.9	LBLT8LED	

High-Performance T8 and Reduced-Wattage T8 New and Baseline Assumptions									
EE Measure Description	EE Cost	System WattsEE	Baseline Description	Base Cost	System Watts Base	Measure Cost	WattsSAVE	Measure Code	Default Loadshape Description
RWT8 - F28T8 Lamp	$4.50	24.64	F32T8 Standard Lamp	$2.50	28.16	$2.00	3.52	LBLRWLT8	Commercial EP Lighting with Cooling Bonus
RWT8 - F28T8 Extra Life Lamp	$4.50	24.64	F32T8 Standard Lamp	$2.50	28.16	$2.00	3.52	LBLRWLT8	
RWT8 - F32/25W T8 Lamp	$4.50	22.00	F32T8 Standard Lamp	$2.50	28.16	$2.00	6.16	LBLRWLT8	
RWT8 - F32/25W T8 Lamp Extra Life	$4.50	22.00	F32T8 Standard Lamp	$2.50	28.16	$2.00	6.16	LBLRWLT8	
RWT8 - F17T8 Lamp - 2 Foot	$4.80	13.80	F17T8 Standard Lamp - 2 foot	$2.80	15.64	$2.00	1.84	LBLRWLT8	
RWT8 - F25T8 Lamp - 3 Foot	$5.10	20.24	F25T8 Standard Lamp - 3 foot	$3.10	23.00	$2.00	2.76	LBLRWLT8	
RWT8 - F30T8 Lamp - 6" Utube	$11.31	26.40	F32T8 Standard Utube Lamp	$9.31	28.16	$2.00	1.76	LBLRWLT8	
RWT8 - F29T8 Lamp - Utube	$11.31	25.52	F32T8 Standard Utube Lamp	$9.31	28.16	$2.00	2.64	LBLRWLT8	
RWT8 - F96T8 Lamp - 8 Foot	$9.00	56.70	F96T8 Standard Lamp - 8 foot	$7.00	61.95	$2.00	5.25	LBLRWLT8	

Reduced Wattage T5 New and Baseline Assumptions									
EE Measure Description	EE Cost	System WattsEE	Baseline Description	Base Cost	System Watts Base	Measure Cost	WattsSAVE	Measure Code	Default Loadshape Description
RWT5 - F14T5 Lamp - 2 Foot	$14.00	13.00	F14T5 Standard Lamp	$12.00	14.00	$2.00	1.00	LBLRWLT5	Commercial EP Lighting with Cooling Bonus
RWT5 - F21T5 Lamp - 3 Foot	$14.00	20.00	F21T5 Standard Lamp	$12.00	21.00	$2.00	1.00	LBLRWLT5	
RWT5 - F28T5 Lamp - 4 Foot	$14.00	26.00	F28T5 Standard Lamp	$12.00	28.00	$2.00	2.00	LBLRWLT5	
RWT5 - F35T5 Lamp - 5 Foot	$14.00	33.00	F35T5 Standard Lamp	$12.00	35.00	$2.00	2.00	LBLRWLT5	
RWT5 - F54T5 Lamp - 4 Foot 44W	$14.00	44.00	F54T5 Standard Lamp	$12.00	54.00	$2.00	10.00	LBLRWLT5	
RWT5 - F54T5 Lamp - 4 Foot 47W	$14.00	47.00	F54T5 Standard Lamp	$12.00	54.00	$2.00	7.00	LBLRWLT5	
RWT5 - F54T5 Lamp - 4 Foot 49W	$14.00	49.00	F54T5 Standard Lamp	$12.00	54.00	$2.00	5.00	LBLRWLT5	
RWT5 - F54T5 Lamp - 4 Foot 51W	$14.00	51.00	F54T5 Standard Lamp	$12.00	54.00	$2.00	3.00	LBLRWLT5	

T**8 LED Replacement Lamps (TLED) Component Costs and Lifetimes**						
EE Measure Description	**EE Lamp Cost**	**EE Lamp Life (hrs)**	**Baseline Description**	**Base Lamp Cost**	**Base Lamp Life (hrs)**	**Base Lamp Rep. Labor Cost**
T8 LED Replacement Lamp (TLED), < 1200 lumens	$17.75	50,000	F17T8 Standard Lamp - 2 foot	$4.49	30,000	$2.67
T8 LED Replacement Lamp (TLED), 1200-2400 lumens	$18.00	50,000	F32T8 Standard Lamp - 4 foot	$3.00	24,000	$2.67
T8 LED Replacement Lamp (TLED), > 2400 lumens	$24.25	50,000	F32T8/HO Standard Lamp - 4 foot	$11.00	18,000	$2.67

High-Performance T8 and Reduced-Wattage T8 Component Costs and Lifetimes						
EE Measure Description	**EE Lamp Cost**	**EE Lamp Life (hrs)**	**Baseline Description**	**Base Lamp Cost**	**Base Lamp Life (hrs)**	**Base Lamp Rep. Labor Cost**
RWT8 - F28T8 Lamp	$4.50	30,000	F32T8 Standard Lamp	$2.50	15,000	$2.67
RWT8 - F28T8 Extra Life Lamp	$4.50	36,000	F32T8 Standard Lamp	$2.50	15,000	$2.67
RWT8 - F32/25W T8 Lamp	$4.50	30,000	F32T8 Standard Lamp	$2.50	15,000	$2.67
RWT8 - F32/25W T8 Lamp Extra Life	$4.50	36,000	F32T8 Standard Lamp	$2.50	15,000	$2.67
RWT8 - F17T8 Lamp - 2 Foot	$4.80	18,000	F17T8 Standard Lamp - 2 foot	$2.80	15,000	$2.67
RWT8 - F25T8 Lamp - 3 Foot	$5.10	18,000	F25T8 Standard Lamp - 3 foot	$3.10	15,000	$2.67
RWT8 - F30T8 Lamp - 6" Utube	$11.31	24,000	F32T8 Standard Utube Lamp	$9.31	15,000	$2.67

RWT8 - F29T8 Lamp - Utube	$11.31	24,000	F32T8 Standard Utube Lamp	$9.31	15,000	$2.67
RWT8 - F96T8 Lamp - 8 Foot	$9.00	24,000	F96T8 Standard Lamp - 8 foot	$7.00	15,000	$2.67

Reduced Wattage T5 Component Costs and Lifetimes						
EE Measure Description	**EE Lamp Cost**	**EE Lamp Life (hrs)**	**Baseline Description**	**Base Lamp Cost**	**Base Lamp Life (hrs)**	**Base Lamp Rep. Labor Cost**
RWT5 - F14T5 Lamp - 2 Foot	$14.00	30,000	F14T5 Standard Lamp	$12.00	20,000	$2.67
RWT5 - F21T5 Lamp - 3 Foot	$14.00	30,000	F21T5 Standard Lamp	$12.00	20,000	$2.67
RWT5 - F28T5 Lamp - 4 Foot	$14.00	30,000	F28T5 Standard Lamp	$12.00	20,000	$2.67
RWT5 - F35T5 Lamp - 5 Foot	$14.00	30,000	F35T5 Standard Lamp	$12.00	20,000	$2.67
RWT5 - F54T5 Lamp - 4 Foot 44W	$14.00	30,000	F54T5 Standard Lamp	$12.00	20,000	$2.67
RWT5 - F54T5 Lamp - 4 Foot 47W	$14.00	30,000	F54T5 Standard Lamp	$12.00	20,000	$2.67
RWT5 - F54T5 Lamp - 4 Foot 49W	$14.00	30,000	F54T5 Standard Lamp	$12.00	20,000	$2.67
RWT5 - F54T5 Lamp - 4 Foot 51W	$14.00	30,000	F54T5 Standard Lamp	$12.00	20,000	$2.67

Footnotes

[1] Per 2005 TAG agreement for prescriptive measures

[2] Lifetime ISR based on methodology from Chapter 21: Residential Lighting Evaluation Protocol of the Uniform Methods Project. Using a 1st Year ISR of 92.5% (average of 1st year ISR of 90% from NMR Group, Inc., "Efficiency Maine Retail Lighting Program Overall Evaluation Report FINAL," 4/16/2015. Page 14, Table 2-1 and 95% from NMR Group, Inc., "Connecticut LED Lighting Study Report (R154) FINAL," 1/28/2016. Page V, Table 1) and a discount rate of 3.00% based on the Vermont societal cost test, the lifetime ISR after three years is 97%.

[3] The default waste heat factor for demand and energy is from KEMA, "NEEP C&I Lighting Loadshape Project, KEMA," 2011. The report modeled the energy savings per building type and the associated energy, demand, and coincident demand interactive effects. A description of how the interactive effects were developed is on page 28 of the report, including details about how temperature balance points, equipment efficiencies, and heat to space factors influenced each building's designated interactive effects. The building types were weighted for the NE-North Weather climate zone in order to come up with a single prescriptive default value for both demand and energy lighting waste heat factors. For more information, please see the spreadsheet, "EVT Lighting WHF Research_Prescriptive.xlsx".

[4] Operating hours are based on Efficiency Vermont data for prescriptive applications from 7/1/2015 through 10/24/2016 for Commercial LED Linear Replacements and from 1/1/2014 through 5/31/2016 for Reduced Wattage T8 and T5. See SMARTLIGHT Reference Tables December2016.xlsx for analysis. Operating hours for residential lamps are based on a household average 2.7 hours of use per day. NMR, "Northeast Residential Lighting Hours-of-Use Study", 5/5/2014. Page 34, Table 3-1.

[5] See 'Lighting Efficiency Waste Heat Adjustment Methodology.doc'

[6] The typical aspect ratio is sourced from PNNL, "Analysis of Daylighting Requirements within ASHRAE Standard 90.1, PNNL," 2013, from the Executive Summary on page v. The aspect ratio is sourced from 1 of 16 PNNL prototype building models. The 60% default value is from the medium office building model.

[7] From "Calculating lighting and HVAC Interactions", Table 1, ASHRAE Journal November 1993.

[8] 2009 ASHRAE Handbook Fundamentals (p. 16.2): "Conventional all-air air-handling systems for commercial and institutional buildings have approximately 10 to 40% outside air."

[9] Based on Commercial "Small" Lighting coincidence factors from KEMA; "C&I Lighting Load Shape Project Final Report," July 19, 2011, prepared for the Regional Evaluation, Measurement and Verification Form, submitted to NEEP. The winter coincidence factor has been adjusted to remove the cooling bonus from winter peak demand.

LED Lighting Systems

Measure Number: I-C-22 I
Portfolio: EVT TRM Portfolio 2017-12
Status: Inactive
Effective Date: 2018/1/1
End Date: 2018/12/31
Program: Business Energy Services
End Use: Lighting

Update Summary

Updates include:

Revision of certain waste heat assumptions (WHFe, WHFd, and AR) that EVT and DPS agreed to during 10/4/2017 TAG.

Referenced Documents

- 2009 ASHRAE Handbook Fundamentals
- Calculating Lighting and HVAC Interactions_ASHRAE
- Lighting Efficiency Waste Heat Adjustment Methodology
- PNNL_Analysis of Daylighting Requirements_Aug 2013
- NEEP_CI Lighting Loadshape_Jul 2011
- EVT Lighting WHF Research_Prescriptive
- LED-lighting-systems-trm-assumptions 2017 v2

Description

The measures included in this TRM are LED lighting technologies intended for installation by commercial and industrial (C&I) customers on retrofit, market opportunity, and new construction projects. LED lighting systems have source efficacies (lumens per watt) that can match or exceed efficacies of incandescent, compact fluorescent, linear fluorescent and HID lighting. In addition, LED's inherent directionality reduces or eliminates the need for a reflector to direct light, thereby reducing or eliminating fixture efficiency losses. Eligible measures include new fixtures and retrofit kits. All measures will be offered through the commercial lighting standard rebate form and through the efficiencyvermont.com on-line rebate application.

Algorithms

Electric Demand Savings

$\Delta kW = ((Watts_{BASE} - Watts_{EE}) / 1000) \times ISR \times WHF_d$

Symbol Table

Electric Energy Savings

$\Delta kWh = ((Watts_{BASE} - Watts_{EE}) / 1000) \times HOURS \times ISR \times WHF_e$

Symbol Table

Heating Increased Usage

Oil heating is assumed typical for commercial buildings.

$\Delta MMBTU_{WH} = (\Delta kWh / WHF_e) \times 0.003413 \times (1 - OA) \times AR \times HF \times DFH / HEff$

Symbol Table

Waste Heat Adjustment

Cooling savings are incorporated into the electric savings algorithm with the waste heat factor (WHF).

Where:

ΔkW = Gross customer connected load kW savings for the measure

ΔkWh = Gross customer annual kWh savings for the measure

$\Delta MMBTU_{WH}$ = Gross customer annual heating MMBTU fuel increased usage for the measure from the reduction in lighting heat.

0.003413 = Conversion from kWh to MMBTU

AR = Typical aspect ratio factor; the default value is 60%[5] and is based on the typical square footage of commercial building within 15 feet of exterior wall. The ASHRAE heating factor applies to perimeter zone heat, therefore it must be adjusted to account for lighting in core zones.

DFH = Percent of lighting in heated spaces. For prescriptive lighting, assumed to be 95%

HEff = Average heating system efficiency, For prescriptive lighting, assumed to be 79% in existing buildings[6]

HF = ASHRAE heating factor of 0.39 for lighting waste heat for Burlington, Vermont[7]

HOURS = Annual lighting hours of use per year; collected from prescriptive application form. If operating hours are not available, then the value will be selected from the 'Interior Lighting Operating Hours by Building Type' table located in the Reference Tables section.

ISR = In service rate, or the percentage of units rebated that actually get used. For prescriptive measures, this is assumed to be 98%.[1]

OA = Outside Air - the average percent of the supply air that is Outside Air, assumed to be 25%[8]

$Watts_{BASE}$ = Baseline connected wattage from table located in Reference Tables section.

$Watts_{EE}$ = Energy efficient connected wattage from table located in Reference Tables section.

WHF_d = Waste heat factor for demand to account for cooling savings from efficient lighting. For prescriptive commercial lighting in existing buildings, the default value is 1.102.[2] The cooling savings are only added to the summer peak savings. For refrigerated case lighting, the value is 1.29 (calculated as (1 + (1.0 / 3.5))). Based on the assumption that all lighting in refrigerated cases is mechanically cooled, with a typical 3.5[3]. COP refrigeration system efficiency, and assuming 100% of lighting heat needs to be mechanically cooled at time of summer peak.

WHF_e = Waste heat factor for energy to account for cooling savings from efficient lighting. For prescriptive commercial lighting in existing buildings, the default value is 1.036.[4] For refrigerated case lighting, the value is 1.29 (calculated as (1 + (1.0 / 3.5))). Based on the assumption that all lighting in refrigerated cases is mechanically cooled, with a typical 3.5 COP refrigeration system efficiency.

Baseline Efficiencies

All measures assume a market opportunity baseline consisting of T8 fluorescent for interior LED measures and pulse-start metal halide or 4-pin CFL for exterior LED measures[9].

High Efficiency

Eligible LED products must be listed on the DesignLights Consortium Qualified Products List. For LED fixtures, measures are grouped into lumen bins with lumen-equivalent baseline technologies[10].

Operating Hours

Operating hours will be collected from the prescriptive application form. If customer-reported operating hours are not available, then the value will be selected from the 'Interior Lighting Operating Hours by Building Type' table located in the Reference Tables section.

Load Shapes

For Interior lighting applications, # 12 (Commercial Indoor Lighting-Blended) for demand and lighting energy savings and #15 (Commercial A/C) for cooling energy savings.

For Exterior lighting applications, #13 (Commercial Outdoor Lighting)

For refrigerated and freezer case lighting applications, # 87 (Grocery/Conv. Store Indoor Lighting) for demand and lighting energy savings and #14 (Commercial Refrigeration) for refrigeration and freezer (cooling bonus) energy savings.

12d Commercial Indoor Lighting - Blended
13a Commercial Outdoor Lighting
14a Commercial Refrigeration
15c Commercial A/C
87b Grocery/Conv. Store Indoor Lighting

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
12	Commercial Indoor Lighting - Blended	Active	48.8 %	19.5 %	22.2 %	9.5 %	46.9 %	67.9 %
13	Commercial Outdoor Lighting	Active	20.5 %	50.6 %	6.1 %	22.8 %	70.2 %	3.7 %
14	Commercial Refrigeration	Active	33.0 %	32.6 %	17.0 %	17.4 %	69.0 %	77.2 %
15	Commercial A/C	Active	18.0 %	10.0 %	46.0 %	26.0 %	0.0 %	34.2 %
87	Grocery/Conv. Store Indoor Lighting	Active	39.7 %	26.7 %	19.7 %	13.9 %	84.7 %	90.8 %

Net Savings Factors

Measures

LFHRCLED	LED Refrigerated Case Lighting
LFH22LED	LED 2x2 Recessed Light Fixture

LFH24LED	LED 2x4 Recessed Light Fixture
LFH14LED	LED 1x4 Recessed Light Fixture
LFHHBLED	LED High- and Low-Bay Fixtures
LFHSLLED	LED Linear Ambient Fixture
LFHEXLED	LED Exterior Fixtures
LFHAGLED	LED Ag Interior Fixtures
LBLHDLED	LED HID Lamp Replacement-Type B/C (direct-wired)

Tracks [Base Track]

6013PRES [is base track]	Pres Equip Rpl
6014PRES [is base track]	6014PRES

Lifetimes

For Fixtures: 15 years

Analysis period is the same as lifetime.

For HID Replacement Lamps:

Lifetime is the life of the product, at the reported operating hours (lamp life in hours divided by operating hours per year – see reference table 'LED Component Costs and Lifetimes' for LED lamp life assumption).

The analysis period is the same as the lifetime, capped at 15 years.

Measure Cost

All measure costs are assumed to be incremental costs vs. the market opportunity baselines. LED costs are based on recent Efficiency Vermont experience and cost estimates provided by the U.S. Department of Energy[11]. Refer to Reference Tables section of this document for incremental measure cost data.

O&M Cost Adjustments

See worksheet "LED TRM Assumptions" within the reference file LED Lighting Systems TRM Assumptions 2017.xlsx for details.

		LED New and Baseline O&M Assumptions							
LED Category	**LED Measure Description**	**LED Lamp Life (hrs)**	**LED Lamp Replacement Cost**	**LED Driver Life (hrs)**	**LED Driver Replacement Cost**	**Baseline Lamp Life (hrs)**	**Baseline Lamp Replacement Cost Combined**	**Baseline Ballast Life (hrs)**	**Baseline Ballast Replacement Cost Combined**
LED Case Fixtures	LED Refrigerated Case Light, Horizontal or Vertical, <= 1700 lumens	50,000	$40.52	70,000	$40.00	24,000	$6.17	40,000	$31.00
	LED Refrigerated Case Light, Horizontal or Vertical, > 1700 lumens	50,000	$64.51	70,000	$40.00	18,000	$13.17	40,000	$56.00
LED Troffers	LED 2x2 Recessed Light Fixture, 2000-3500 lumens	50,000	$78.30	70,000	$40.00	24,000	$26.33	40,000	$35.00
	LED 2x2 Recessed Light Fixture, 3501-5000 lumens	50,000	$87.76	70,000	$40.00	24,000	$39.50	40,000	$35.00
	LED 2x4 Recessed Light Fixture, 3000-4500 lumens	50,000	$95.49	70,000	$40.00	24,000	$12.33	40,000	$35.00
	LED 2x4 Recessed Light Fixture, 4501-6000 lumens	50,000	$113.40	70,000	$40.00	24,000	$18.50	40,000	$35.00
	LED 2x4 Recessed Light Fixture, 6001-7500 lumens	50,000	$136.52	70,000	$40.00	24,000	$24.67	40,000	$35.00
	LED 1x4 Recessed Light Fixture, 1500-3000 lumens	50,000	$65.43	70,000	$40.00	24,000	$6.17	40,000	$35.00
	LED 1x4 Recessed Light Fixture, 3001-4500 lumens	50,000	$99.99	70,000	$40.00	24,000	$12.33	40,000	$35.00

	LED 1x4 Recessed Light Fixture, 4501-6000 lumens	50,000	$108.28	70,000	$40.00	24,000	$18.50	40,000	$35.00
LED Linear Ambient Fixtures	LED Surface & Suspended Linear Fixture, <= 3000 lumens	50,000	$62.05	70,000	$40.00	24,000	$6.17	40,000	$35.00
	LED Surface & Suspended Linear Fixture, 3001-4500 lumens	50,000	$93.14	70,000	$40.00	24,000	$12.33	40,000	$35.00
	LED Surface & Suspended Linear Fixture, 4501-6000 lumens	50,000	$113.96	70,000	$40.00	24,000	$18.50	40,000	$35.00
	LED Surface & Suspended Linear Fixture, 6001-7500 lumens	50,000	$152.32	70,000	$40.00	30,000	$26.33	40,000	$60.00
	LED Surface & Suspended Linear Fixture, > 7500 lumens	50,000	$194.8	70,000	$40.00	30,000	$39.50	40,000	$60.00
LED High & Low Bay Fixtures	LED Low-Bay Fixtures, <= 10,000 lumens	50,000	$113.51	70,000	$62.50	18,000	$64.50	40,000	$92.50
	LED High-Bay Fixtures, 10,001-15,000 lumens	50,000	$185.39	70,000	$62.50	18,000	$86.00	40,000	$92.50
	LED High-Bay Fixtures, 15,001-20,000 lumens	50,000	$244.08	70,000	$62.50	18,000	$129.00	40,000	$117.50
	LED High-Bay Fixtures, > 20,000 lumens	50,000	$297.87	70,000	$62.50	18,000	$172.00	40,000	$142.50
LED Agricultural Interior Fixtures	LED Ag Interior Fixtures, <= 2,000 lumens	50,000	$41.20	70,000	$40.00	1,000	$1.23	40,000	$26.25
	LED Ag Interior Fixtures, 2,001-4,000 lumens	50,000	$66.13	70,000	$40.00	1,000	$1.43	40,000	$26.25
	LED Ag Interior Fixtures, 4,001-6,000 lumens	50,000	$78.67	70,000	$40.00	1,000	$1.62	40,000	$26.25
	LED Ag Interior Fixtures, 6,001-8,000 lumens	50,000	$105.54	70,000	$40.00	1,000	$1.81	40,000	$26.25
	LED Ag Interior Fixtures, 8,001-12,000 lumens	50,000	$180.03	70,000	$62.50	15,000	$63.00	40,000	$112.50
	LED Ag Interior Fixtures, 12,001-16,000 lumens	50,000	$190.86	70,000	$62.50	15,000	$68.00	40,000	$122.50
	LED Ag Interior Fixtures, 16,001-20,000 lumens	50,000	$237.71	70,000	$62.50	15,000	$73.00	40,000	$132.50
	LED Ag Interior Fixtures, > 20,000 lumens	50,000	$331.73	70,000	$62.50	15,000	$136.00	40,000	$202.50
LED Exterior Fixtures	LED Exterior Fixtures, <= 2,000 lumens	50,000	$55.57	70,000	$62.50	15,000	$9.17	40,000	$50.00
	LED Exterior Fixtures, 2,001-5,000 lumens	50,000	$81.46	70,000	$62.50	15,000	$58.00	40,000	$102.50
	LED Exterior Fixtures, 5,001-10,000 lumens	50,000	$124.05	70,000	$62.50	15,000	$63.00	40,000	$112.50
	LED Exterior Fixtures, 10,001-15,000 lumens	50,000	$213.35	70,000	$62.50	15,000	$68.00	40,000	$122.50
	LED Exterior Fixtures, > 15,000 lumens	50,000	$326.50	70,000	$62.50	15,000	$73.00	40,000	$132.50
LED Mogul Base HID Replacement Lamps	LED Mogul Base HID Replacement Lamps Type B/C, <= 5,000 lumens	50,000	$75.00	70,000	$62.50	15,000	$58.00	40,000	$102.50
	LED Mogul Base HID Replacement Lamps Type B/C, 5,001-10,000 lumens	50,000	$108.78	70,000	$62.50	15,000	$63.00	40,000	$112.50
	LED Mogul Base HID Replacement Lamps Type B/C, 10,001-15,000 lumens	50,000	$160.06	70,000	$62.50	15,000	$68.00	40,000	$122.50
	LED Mogul Base HID Replacement Lamps Type B/C, > 15,000 lumens	50,000	$215.45	70,000	$62.50	15,000	$73.00	40,000	$132.50

Fossil Fuel Description

See algorithm in ‘Heating Increased Usage’

Water Descriptions

There are no water algorithms or default values for this measure.

Reference Tables

Interior Lighting Operating Hours by Building Type

Building Type	Annual Hours
Grocery/Convenience Store	6,019
Hospital	4,007
K-12 Schools	2,456
Lodging/Hospitality	4,808
Manufacturing	4,781
Office	3,642
Public Assembly	3,035
Public Safety	3,116
Religious	2,648
Restaurant	4,089
Retail	4,103
Service	3,521
University/College	3,416
Warehouse	4,009

From C&I Lighting Load Shape Project FINAL Report, July 19, 2011, prepared by KEMA for NEEP. See document NEEP CI Lighting LS FINAL Report_ver 5_7-19-11.pdf

LED New and Baseline Assumptions. See 'LED Lighting Systems TRM Assumptions 2017.xlsx' for details.

Note Efficiency Vermont plan initially to use the average or "Blended" wattage but are considering adding a higher incentive for Premium lamps. If we proceed we would then use the Standard/Premium wattages below.

New Measure Categories 7.1.2017

LED New and Baseline Assumptions

LED Category	LED Measure Description	WattsEE (DLC Blended)	WattsEE (DLC Standard)	WattsEE (DLC Premium)	Baseline Description	WattsBASE	Delta Watts (DLC Blended)	Delta Watts (DLC Standard)	Delta Watts (DLC Premium)	Incremental Cost	Measure Code
LED Case Fixtures	LED Refrigerated Case Light, Horizontal or Vertical, <= 1700 lumens	10.5	10.5	N/A	T8 1L-F32 w/ Elec - 4'	32	21.5	21.5	N/A	$37	LFHRCLED
	LED Refrigerated Case Light, Horizontal or Vertical, > 1700 lumens	22.1	22.1	N/A	T5HO 1L-F54T5HO - 4'	59	36.9	36.9	N/A	$38	LFHRCLED
	LED 2x2 Recessed Light Fixture, 2000-3500 lumens	25.4	26.2	23.4	T8 U-Tube 2L-FB32 w/ Elec - 2'	59	33.6	32.8	35.6	$53	LFH22LED
	LED 2x2 Recessed Light Fixture, 3501-5000 lumens	36.7	37.8	34.2	T8 U-Tube 3L-FB32 w/ Elec - 2'	88	51.3	50.2	53.8	$66	LFH22LED
	LED 2x4										

LED Troffers	Recessed Light Fixture, 3000-4500 lumens	33.3	34.5	30.7	T8 2L-F32 w/ Elec - 4'	59	25.7	24.5	28.3	$50	LFH24LED
	LED 2x4 Recessed Light Fixture, 4501-6000 lumens	44.8	46.8	41.4	T8 3L-F32 w/ Elec - 4'	88	43.2	41.2	46.6	$70	LFH24LED
	LED 2x4 Recessed Light Fixture, 6001-7500 lumens	57.2	60.4	52.3	T8 4L-F32 w/ Elec - 4'	114	56.8	53.6	61.7	$97	LFH24LED
	LED 1x4 Recessed Light Fixture, 1500-3000 lumens	21.8	22.2	19.7	T8 1L-F32 w/ Elec - 4'	32	10.2	9.8	12.3	$22	LFH14LED
	LED 1x4 Recessed Light Fixture, 3001-4500 lumens	33.7	34.3	30.9	T8 2L-F32 w/ Elec - 4'	59	25.3	24.7	28.1	$75	LFH14LED
	LED 1x4 Recessed Light Fixture, 4501-6000 lumens	43.3	44.7	41	T8 3L-F32 w/ Elec - 4'	88	44.7	43.3	47	$84	LFH14LED
LED Linear Ambient Fixtures	LED Surface & Suspended Linear Fixture, <= 3000 lumens	19.5	19.6	19.2	T8 1L-F32 w/ Elec - 4'	32	12.5	12.4	12.8	$8	LFHSLLED
	LED Surface & Suspended Linear Fixture, 3001-4500 lumens	32.1	33	29.6	T8 2L-F32 w/ Elec - 4'	59	26.9	26	29.4	$49	LFHSLLED
	LED Surface & Suspended Linear Fixture, 4501-6000 lumens	43.5	44.4	41.4	T8 3L-F32 w/ Elec - 4'	88	44.5	43.6	46.6	$75	LFHSLLED
	LED Surface & Suspended Linear Fixture, 6001-7500 lumens	56.3	57.8	52	T5HO 2L-F54T5HO - 4'	120	63.7	62.2	68	$127	LFHSLLED
	LED Surface & Suspended Linear Fixture, > 7500 lumens	82.8	84.7	77.8	T5HO 3L-F54T5HO - 4'	180	97.2	95.3	102.2	$184	LFHSLLED
LED High & Low Bay Fixtures	LED Low-Bay Fixtures, <= 10,000 lumens	61.6	64.2	57.2	T8HO 3L-F48/HO Low-Bay	157	95.4	92.8	99.8	$73	LFHHBLED
	LED High-Bay Fixtures, 10,001-15,000 lumens	99.5	103.8	93.3	T8HO 4L-F48/HO High-Bay	196	96.5	92.2	102.7	$124	LFHHBLED
	LED High-Bay Fixtures, 15,001-20,000 lumens	140.2	147.1	130.8	T8HO 6L-F48/HO High-Bay	294	153.8	146.9	163.2	$183	LFHHBLED
	LED High-Bay Fixtures, > 20,000 lumens	193.8	202.5	183.1	T8HO 8L-F48/HO High-Bay	392	198.2	189.5	208.9	$232	LFHHBLED
	LED Ag Interior Fixtures, <= 2,000 lumens	12.9	12.8	18.8	25% 73 Watt EISA Inc, 75% 1L T8	42	29.1	29.2	23.2	$17	LFHAGLED
	LED Ag Interior Fixtures, 2,001-4,000 lumens	29.7	30	26.7	25% 146 Watt EISA Inc, 75% 2L T8	81	51.3	51	54.3	$47	LFHAGLED
	LED Ag Interior Fixtures, 4,001-6,000 lumens	45.1	46	42	25% 217 Watt EISA Inc, 75% 3L T8	121	75.9	75	79	$53	LFHAGLED
	LED Ag Interior				25% 292						

LED Agricultural Interior Fixtures	LED Ag Interior Fixtures, 6,001-8,000 lumens	59.7	61.7	54.6	Watt EISA Inc, 75% 4L T8	159	99.3	97.3	104.4	$86	LFHAGLED
	LED Ag Interior Fixtures, 8,001-12,000 lumens	84.9	88.1	77.8	200W Pulse Start Metal Halide	227.3	142.4	139.2	149.5	$166	LFHAGLED
	LED Ag Interior Fixtures, 12,001-16,000 lumens	113.9	119.8	104.3	320W Pulse Start Metal Halide	363.6	249.7	243.8	259.4	$147	LFHAGLED
	LED Ag Interior Fixtures, 16,001-20,000 lumens	143.7	150.2	134.1	350W Pulse Start Metal Halide	397.7	254	247.5	263.6	$201	LFHAGLED
	LED Ag Interior Fixtures, > 20,000 lumens	193.8	202	183.4	(2) 320W Pulse Start Metal Halide	727.3	533.4	525.3	543.9	$350	LFHAGLED
LED Exterior Fixtures	LED Exterior Fixtures, <= 2,000 lumens	15.8	16.1	13.5	42W 4-pin CFL	47	31.2	30.9	33.5	$108	LFHEXLED
	LED Exterior Fixtures, 2,001-5,000 lumens	35.8	36.5	32.3	100W Metal Halide	113.6	77.9	77.1	81.4	$142	LFHEXLED
	LED Exterior Fixtures, 5,001-10,000 lumens	67.2	68.7	61.3	175W Pulse Start Metal Halide	198.9	131.7	130.2	137.6	$246	LFHEXLED
	LED Exterior Fixtures, 10,001-15,000 lumens	108.8	110.9	101.3	250W Pulse Start Metal Halide	284.1	175.3	173.1	182.8	$305	LFHEXLED
	LED Exterior Fixtures, > 15,000 lumens	183.9	188.2	171.3	400W Pulse Start Metal Halide	454.5	270.7	266.4	283.2	$457	LFHEXLED
LED Mogul Base HID Replacement Lamps	LED Mogul Base HID Replacement Lamps Type B/C, <= 5,000 lumens	33.9	33.9	N/A	100W Metal Halide	113.6	79.7	79.7	N/A	$67	LBLHDLED
	LED Mogul Base HID Replacement Lamps Type B/C, 5,001-10,000 lumens	62.6	62.6	N/A	175W Pulse Start Metal Halide	198.9	136.3	136.3	N/A	$124	LBLHDLED
	LED Mogul Base HID Replacement Lamps Type B/C, 10,001-15,000 lumens	108	108	N/A	250W Pulse Start Metal Halide	284.1	176.1	176.1	N/A	$127	LBLHDLED
	LED Mogul Base HID Replacement Lamps Type B/C, > 15,000 lumens	151.8	151.8	N/A	400W Pulse Start Metal Halide	454.5	302.8	302.8	N/A	$119	LBLHDLED

Measure Categories Prior to 7.1. 2017

LED Category	LED Measure Description	WattsEE	Baseline Description	WattsBASE	Delta Watts	Incremental Cost	Measure Code
LED Downlight Fixtures	LED Recessed, Surface, Pendant Downlights	17.6	Baseline LED Recessed, Surface, Pendant Downlights	54.3	36.7	$27	LFHRDLED
LED Interior Directional	LED Track Lighting	12.2	Baseline LED Track Lighting	60.4	48.2	$59	LFHDHLED
	LED Wall-Wash Fixtures	8.3	Baseline LED Wall-Wash Fixtures	17.7	9.4	$59	LFHWWLED
LED Display Case	LED Display Case Light Fixture	7.1 per ft	Baseline LED Display Case Light Fixture	36.2 per ft	29.1 per ft	$11/ft	LFHDCLED
	LED Undercabinet Shelf-Mounted Task Light Fixtures	7.1 per ft	Baseline LED Undercabinet Shelf-Mounted Task Light Fixtures	36.2 per ft	29.1 per ft	$11/ft	LFHUSLED

	LED Refrigerated Case Light, Horizontal or Vertical	7.6 per ft	Baseline LED Refrigerated Case Light, Horizontal or Vertical (per foot)	15.2 per ft	7.6 per ft	$11/ft	LFHRCLED
	LED Freezer Case Light, Horizontal or Vertical	7.7 per ft	Baseline LED Freezer Case Light, Horizontal or Vertical (per foot)	18.7 per ft	11.0 per ft	$11/ft	LFHFCLED
LED Linear Replacement Lamps	LED 4' Linear Replacement Lamp	18.7	T8 F32 w/ Elec - 4' - per lamp	29.1	10.4	$24	LBL4TLED
	LED 2' Linear Replacement Lamp	9.7	T8 F24 w/ Elec - 2' - per lamp	16	6.3	$13	LBL4TLED
LED Exterior Fixtures	LED Exterior Fixtures, <= 5,000 lumens	42.6	100W Metal Halide	113.6	71	$190	LFHEXLED

Footnotes

[1] 2005 TAG Agreement.

[2] The default waste heat factor for demand and energy is from KEMA, "NEEP C&I Lighting Loadshape Project, KEMA," 2011. The report modeled the energy savings per building type and the associated energy, demand, and coincident demand interactive effects. A description of how the interactive effects were developed is on page 28 of the report, including details about how temperature balance points, equipment efficiencies, and heat to space factors influenced each building's designated interactive effects. The building types were weighted for the NE-North Weather climate zone in order to come up with a single prescriptive default value for both demand and energy lighting waste heat factors. For more information, please see the spreadsheet, "EVT Lighting WHF Research_Prescriptive.xlsx".

[3] Assumes 3.5 COP for medium temp cases based on the average of standard reciprocating and discus compressor efficiencies with Saturated Suction Temperatures of 20°F and a condensing temperature of 90°F.

[4] The default waste heat factor for demand and energy is from KEMA, "NEEP C&I Lighting Loadshape Project, KEMA," 2011. The report modeled the energy savings per building type and the associated energy, demand, and coincident demand interactive effects. A description of how the interactive effects were developed is on page 28 of the report, including details about how temperature balance points, equipment efficiencies, and heat to space factors influenced each building's designated interactive effects. The building types were weighted for the NE-North Weather climate zone in order to come up with a single prescriptive default value for both demand and energy lighting waste heat factors. For more information, please see the spreadsheet, "EVT Lighting WHF Research_Prescriptive.xlsx".

[5] The typical aspect ratio is sourced from PNNL, "Analysis of Daylighting Requirements within ASHRAE Standard 90.1, PNNL," 2013, from the Executive Summary on page v. The aspect ratio is sourced from 1 of 16 PNNL prototype building models. The 60% default value is from the medium office building model.

[6] See 'Lighting Efficiency Waste Heat Adjustment Methodology.doc'

[7] From "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993

[8] 2009 ASHRAE Handbook Fundamentals (p. 16.2): "Conventional all-air air-handling systems for commercial and institutional buildings have approximately 10 to 40% outside air."

[9] Based on results from the 2016 Vermont Business Sector Market Characterization and Assessment Study.

[10] See worksheet "WattsBase (Lumen Analysis)" within the reference file LED Lighting TRM Assumptions 062017.xlsx for details. The following methodology was used in establishing lumen bins and baseline/LED lumen equivalency:

- Define lumen bin ranges that are consistent sizes while reasonably balancing the distribution of DLC qualified products across the bins. Regular/consistent bin increments are preferred in order to reduce confusion for both customers and EVT implementation staff.
- Define baseline technology types for each lumen bin using actual equipment and not a hypothetical calculated baseline.
- Calculate the delivered lumens for each baseline technology. [Baseline delivered lumens = lamp qty x mean lamp lumens x ballast factor x fixture efficiency].
- Calculate the LED initial lumen output that would be equivalent to the baseline. Note that LED fixtures have no ballast factor and fixture efficiency is not applicable due to absolute photometry. [LED initial lumens = baseline delivered lumens / LED lumen maintenance]. Every attempt will be made to reasonably center the LED lumen output within a lumen bin, however the goals of consistent bin increments and baselines made up of actual equipment will result in some LED lumen values being uncentered within a lumen bin.

[11] See worksheet "EE Cost (EVT Program Data)" within the reference file LED Lighting Systems TRM Assumptions 062017.xlsx for details.

Lighting Controls

Measure Number: I-C-5 m
Portfolio: EVT TRM Portfolio 2018-03
Status: Active
Effective Date: 2018/1/1
End Date: [None]
Program: Business Energy Services
End Use: Lighting

Update Summary

Updates include:

- Revision of waste heat assumptions (WHFe, WHFd, and AR) that EVT and DPS agreed to during 10/4/2017 TAG.
- Update to watts controlled assumptions based on more recent program data.
- Clarification of *Integrated* Dual Occupancy / Daylight Sensors.
- Addition of Integrated Occupancy Sensors
- Updates to costs of integrated controls
- Edits to Measure Codes to allow future distinction between application types

Referenced Documents

- Calculating Lighting and HVAC Interactions_ASHRAE
- NEEP CI Lighting LS FINAL Report_ver 5_7-19-11
- KEMA Lighting Controls Summary of Findings
- LBNL Lighting Controls in Commercial Buildings 2012
- PNNL_Analysis of Daylighting Requirements_Aug 2013
- NEEP_CI Lighting Loadshape_Jul 2011
- EVT Lighting WHF Research_Prescriptive
- Application Assessment of Bi-Level LED Parking Lot Lighting
- kroger_case_study_final[1]
- WS-CaseStudy-Walmart_OccupancySensors
- EVT Lighting Control Assumptions2018

Description

Controls for interior & exterior lighting, including occupancy sensors and daylight sensors.

Algorithms

Electric Demand Savings

$$\Delta kW = kW_{connected} \times SVG \times OTF \times ISR \times WHF_d$$

Symbol Table

Electric Energy Savings

$$\Delta kWh = kW_{connected} \times HOURS \times SVG \times OTF \times ISR \times WHF_e$$

Symbol Table

Heating Increased Usage

Oil heating is assumed typical for commercial buildings.

$$\Delta MMBTU_{WH} = (\Delta kWh / WHF_e) \times 0.003413 \times (1 - OA) \times AR \times HF \times DFH / HEff$$

Where:

ΔkW = gross customer connected load kW savings for the measure. This number represents the maximum summer kW savings – including the reduced cooling load from the more efficient lighting.

ΔkWh = gross customer annual kWh savings for the measure (includes the reduced cooling load from the more efficient lighting)

$\Delta MMBTU_{WH}$ = Gross customer annual heating MMBTU fuel increased usage for the measure from the reduction in lighting heat.

AR = Typical aspect ratio factor; the default value is 60%[5] and is based on the typical square footage of commercial building within 15 feet of exterior wall. The ASHRAE heating factor applies to perimeter zone heat, therefore it must be adjusted to account for lighting in core zones.

DFH = Percent of lighting in heated spaces. For prescriptive lighting, assumed to be 95%

HEff = Average heating system efficiency. For prescriptive lighting assumed to be 79% in existing buildings.[6]

HF = ASHRAE heating factor of 0.39 for lighting waste heat for Burlington, Vermont[7]

HOURS = The lighting operating hours are collected from the prescriptive application form. If not available, then assume hours per year from the table titled Lighting Operating Hours by Building Type.

ISR = In service rate, or the percentage of units rebated that actually get used. For prescriptive measures, this is assumed to be 98%.[1]

$kW_{connected}$ = kW lighting load connected to control. For multi-level and perimeter switching in the Comprehensive Track the savings is applied to all interior lighting kW load.

OA = Outside Air - the average percent of the supply air that is Outside Air, assumed to be 25%.[8]

OTF = Operational Testing Factor. OTF = 1.0 for all occupancy sensors and for daylight dimming controls when the project undergoes Operational Testing or commissioning services, 0.80 for daylight dimming controls otherwise.

SVG = % of annual lighting energy saved by lighting control; determined on a site-specific basis or refer to table by control type

WHF_d = Waste heat factor for demand to account for cooling savings from efficient lighting. For prescriptive commercial lighting in existing buildings, the default value is 1.102.[2] The cooling savings are only added to the summer peak savings. For refrigerated case lighting, the value is 1.29 (calculated as (1 + (1.0 / 3.5))). Based on the assumption that all lighting in refrigerated cases is mechanically cooled, with a typical 3.5[3]. COP refrigeration system efficiency, and assuming 100% of lighting heat needs to be mechanically cooled at time of summer peak.

WHF_e = Waste heat factor for energy to account for cooling savings from efficient lighting. For prescriptive commercial lighting in existing buildings, the default value is 1.036.[4] For refrigerated case lighting, the value is 1.29 (calculated as (1 + (1.0 / 3.5))). Based on the assumption that all lighting in refrigerated cases is mechanically cooled, with a typical 3.5 COP refrigeration system efficiency.

Baseline Efficiencies

This TRM applies only to Prescriptive Projects, or those projects less than 10,000 Square Feet and less than 250 rebate-eligible items, by agreement with DPS. Analysis of Occupancy Sensors and Daylight Dimming on custom projects will be calculated on a custom basis using the actual site conditions including existing controls where appropriate.

High Efficiency

Controlled lighting such as occupancy sensors and daylight dimming.

Load Shapes

12d Commercial Indoor Lighting - Blended
15c Commercial A/C

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
12	Commercial Indoor Lighting - Blended	Active	48.8 %	19.5 %	22.2 %	9.5 %	46.9 %	67.9 %
15	Commercial A/C	Active	18.0 %	10.0 %	46.0 %	26.0 %	0.0 %	34.2 %

Net Savings Factors

Measures

LECOCCEX	Exterior Occupancy Sensors
LECOCCRE	Refrigerator Case Controls
LECOCCFR	Freezer Case Controls
LECOCCDL	Fixture-Mounted Dual Occupancy & Daylight Sensor
LECOCCFX	Fixture-Mounted Occupancy Sensor
LECOCCRM	Remote-Mounted Occupancy Sensor
LECDAYFX	Fixture-Mounted Daylight Sensor
LECOCCIN	Integrated Occupancy Sensor for LED Interior Fixtures
LECOCCWS	Wall Switch Occupancy Sensor
LECDAYRM	Remote Mounted Daylight Sensor

LECOCCID	Integrated Dual Occupancy & Daylight Sensor for LED Interior Fixtures

Tracks [Base Track]

6012CNIR [is base track]	C&I Retro
6013CUST [is base track]	Cust Equip Rpl
6013PRES [is base track]	Pres Equip Rpl

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
C&I Retro	6012CNIR	LECOCCEX	0.89	1.00
C&I Retro	6012CNIR	LECOCCRE	0.89	1.00
C&I Retro	6012CNIR	LECOCCFR	0.89	1.00
C&I Retro	6012CNIR	LECOCCDL	0.89	1.00
Cust Equip Rpl	6013CUST	LECOCCEX	0.97	1.00
Cust Equip Rpl	6013CUST	LECOCCRE	0.97	1.00
Cust Equip Rpl	6013CUST	LECOCCFR	0.97	1.00
Cust Equip Rpl	6013CUST	LECOCCDL	0.97	1.00
Pres Equip Rpl	6013PRES	LECOCCEX	0.98	1.00
Pres Equip Rpl	6013PRES	LECOCCRE	0.98	1.00
Pres Equip Rpl	6013PRES	LECOCCFR	0.98	1.00
Pres Equip Rpl	6013PRES	LECOCCDL	0.98	1.00
C&I Retro	6012CNIR	LECOCCFX	0.89	1.00
Cust Equip Rpl	6013CUST	LECOCCFX	0.97	1.00
Pres Equip Rpl	6013PRES	LECOCCFX	0.98	1.00
C&I Retro	6012CNIR	LECOCCRM	0.89	1.00
Cust Equip Rpl	6013CUST	LECOCCRM	0.97	1.00
Pres Equip Rpl	6013PRES	LECOCCRM	0.98	1.00
C&I Retro	6012CNIR	LECDAYFX	0.89	1.00
Cust Equip Rpl	6013CUST	LECDAYFX	0.97	1.00
Pres Equip Rpl	6013PRES	LECDAYFX	0.98	1.00
C&I Retro	6012CNIR	LECOCCIN	0.89	1.00
Cust Equip Rpl	6013CUST	LECOCCIN	0.97	1.00
Pres Equip Rpl	6013PRES	LECOCCIN	0.98	1.00
C&I Retro	6012CNIR	LECOCCWS	0.89	1.00
Cust Equip Rpl	6013CUST	LECOCCWS	0.97	1.00
Pres Equip Rpl	6013PRES	LECOCCWS	0.98	1.00
C&I Retro	6012CNIR	LECDAYRM	0.89	1.00
Cust Equip Rpl	6013CUST	LECDAYRM	0.97	1.00
Pres Equip Rpl	6013PRES	LECDAYRM	0.98	1.00
C&I Retro	6012CNIR	LECOCCID	0.89	1.00
Cust Equip Rpl	6013CUST	LECOCCID	0.97	1.00
Pres Equip Rpl	6013PRES	LECOCCID	0.98	1.00

Persistence

The persistence factor is assumed to be one.

Lifetimes

Controls – 10 years. Analysis period is the same as the lifetime.

Measure Cost

Lighting Control Type	Location	Incremental Cost
Wall Switch Occupancy Sensor	Interior	$55
Fixture-Mounted Occupancy Sensor	Interior	$67
Remote-Mounted Occupancy Sensor	Interior	$125
Fixture-Mounted Daylight Sensor	Interior	$50
Remote-Mounted Daylight Sensor	Interior	$65
Integrated Occupancy Sensor	Interior	$40
Integrated Dual Occupancy & Daylight Sensor	Interior	$50
Fixture-Mounted Dual Occupancy & Daylight Sensor	Interior	$100
Refrigerator Case Occupancy Sensor	Interior	$60
Freezer Case Occupancy Sensor	Interior	$60

Exterior Occupancy Sensor	Exterior	$82

See 'EVT Lighting Control Assumptions_2018.xlsx'; "Cost" sheet for more information.

O&M Cost Adjustments

N/A

Reference Tables

Lighting Control Type	Measure Code	Location	% Savings (SVG)[9]	Default Controlled Wattage[10]
Wall Switch Occupancy Sensor	LECOCCWS	Interior	24%	84
Fixture-Mounted Occupancy Sensor	LECOCCFX	Interior	24%	81
Remote-Mounted Occupancy Sensor	LECOCCRM	Interior	24%	338
Fixture-Mounted Daylight Sensor	LECDAYFX	Interior	28%	95
Remote-Mounted Daylight Sensor	LECDAYRM	Interior	28%	239
Integrated Occupancy Sensor for LED Interior Fixtures < 10,000 Lumens	LECOCCIN	Interior	24%	31
Integrated Occupancy Sensor for LED Interior Fixtures >= 10,000 Lumens	LECOCCIN	Interior	24%	118
Integrated Dual Occupancy & Daylight Sensor for LED Interior Fixtures < 10,000 Lumens	LECOCCID	Interior	38%	31
Integrated Dual Occupancy & Daylight Sensor for LED Interior Fixtures >= 10,000 Lumens	LECOCCID	Interior	38%	118
Fixture-Mounted Dual Occupancy & Daylight Sensor for LED Interior Fixtures < 10,000 Lumens	LECOCCDL	Interior	38%	31
Fixture-Mounted Dual Occupancy & Daylight Sensor for LED Interior Fixtures >= 10,000 Lumens	LECOCCDL	Interior	38%	118
Refrigerator Case Occupancy Sensor	LECOCCRE	Interior	40%	92
Freezer Case Occupancy Sensor	LECOCCFR	Interior	40%	90
Exterior Occupancy Sensor	LECOCCEX	Exterior	41%	86

Lighting Operating Hours by Building Type

Building Type	**Annual Hours**
Grocery/Convenience Store	6,019
Hospital	4,007
K-12 Schools	2,456
Lodging/Hospitality	4,808
Manufacturing	4,781

Office	3,642
Public Assembly	3,035
Public Safety	3,116
Religious	2,648
Restaurant	4,089
Retail	4,103
Service	3,521
University/College	3,416
Warehouse	4,009
Exterior	3,338

From C&I Lighting Load Shape Project FINAL Report, July 19, 2011, prepared by KEMA for NEEP. See document NEEP CI Lighting LS FINAL Report_ver 5_7-19-11.pdf. Exterior Lighting hours based on estimated mix of photocell-controlled lighting (12 hpd) and switch-controlled lighting.

Footnotes

[1] 2005 TAG agreement.

[2] The default waste heat factor for demand and energy is from KEMA, "NEEP C&I Lighting Loadshape Project, KEMA," 2011. The report modeled the energy savings per building type and the associated energy, demand, and coincident demand interactive effects. A description of how the interactive effects were developed is on page 28 of the report, including details about how temperature balance points, equipment efficiencies, and heat to space factors influenced each building's designated interactive effects. The building types were weighted for the NE-North Weather climate zone in order to come up with a single prescriptive default value for both demand and energy lighting waste heat factors. For more information, please see the spreadsheet, "EVT Lighting WHF Research_Prescriptive.xlsx".

[3] Assumes 3.5 COP for medium temp cases based on the average of standard reciprocating and discus compressor efficiencies with Saturated Suction Temperatures of 20°F and a condensing temperature of 90°F.

[4] The default waste heat factor for demand and energy is from KEMA, "NEEP C&I Lighting Loadshape Project, KEMA," 2011. The report modeled the energy savings per building type and the associated energy, demand, and coincident demand interactive effects. A description of how the interactive effects were developed is on page 28 of the report, including details about how temperature balance points, equipment efficiencies, and heat to space factors influenced each building's designated interactive effects. The building types were weighted for the NE-North Weather climate zone in order to come up with a single prescriptive default value for both demand and energy lighting waste heat factors. For more information, please see the spreadsheet, "EVT Lighting WHF Research_Prescriptive.xlsx".

[5] The typical aspect ratio is sourced from PNNL, "Analysis of Daylighting Requirements within ASHRAE Standard 90.1, PNNL," 2013, from the Executive Summary on page v. The aspect ratio is sourced from 1 of 16 PNNL prototype building models. The 60% default value is from the medium office building model.

[6] See 'Lighting Efficiency Waste Heat Adjustment Methodology.doc'

[7] From "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993.

[8] 2009 ASHRAE Handbook Fundamentals (p. 16.2): "Conventional all-air air-handling systems for commercial and institutional buildings have approximately 10 to 40% outside air."

[9] Interior controls % savings based on LBNL, Williams et al, "Lighting Controls in Commercial Buildings", 2012, p172. Case occupancy sensors are based on case studies of controls installed in Wal-Mart and Krogers refrigerator/freezer LED case lighting controls and exterior sensors are based upon data from "Application Assessment of Bi-Level LED Parking Lot Lighting" p6.

See 'EVT Lighting Control Assumptions_2018.xlsx' for more information.

[10] Based on Efficiency Vermont data from program year 2017. See 'EVT Lighting Control Assumptions_2018.xls'; "TRM Table" sheet for details on calculations.

Maple Sap Vacuum Pump VFD

Measure Number: I-A-10 b
Portfolio: EVT TRM Portfolio 2017-11
Status: Active
Effective Date: 2018/1/1
End Date: [None]
Program: Business Energy Services
End Use: Motors

Update Summary

- Due to the relatively low volume of measures prescriptively implemented, this measure was not opted for a major algorithm overhaul, but rather an update based on aggregate savings claims and cost data from prior custom projects. The original characterization of this measure claimed savings based on an average from custom pilot projects implemented from 2010-2012.
- I drilled down on the measure savings and costs from these prior custom projects, updating the existing aggregates from a per unit basis to a per horsepower basis. I uploaded a new analysis workbook reflecting savings and costs on both a per unit and per horsepower basis.

Referenced Documents

- Maple-Sap-VFD-Analysis_v3

Description

The measure is a VFD attached to the vacuum pump in a maple sap extraction system that allows operators to manage system pressure by reducing pump speed rather than by using an inefficient method such as a differential pressure relief valve.

Estimated Measure Impacts

	Average Annual MWH Savings per unit	Average number of measures per year[1]	Average Annual MWH Savings per year
Maple Sap Vacuum Pump VFD	1.81	18	32.52

Algorithms

Electric Demand Savings

ΔkW	= kW/HP x HP

Symbol Table

Electric Energy Savings

ΔkWh	= kWh/HP x HP

Where:

ΔkW	=	gross customer connected load kW savings for the measure
ΔkWh	=	gross customer average annual kWh savings for the measure
HP	=	horsepower of the motor to which the VFD is applied
kW/HP	=	0.12[2]
kWh/HP	=	155[2]

Savings estimates are the average savings claimed per motor horsepower for EVT custom projects in 2010, 2011, and 2012, see Maple Sap VFD_Analysis_v2.xls

Baseline Efficiencies

The baseline reflects a maple sap extraction system without a VFD equipped vacuum pump.

High Efficiency

The high efficiency case is installation and use of a VFD equipped vacuum pump.

Operating Hours

N/A

Load Shapes

112a Maple Sap VFD

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
112	Maple Sap VFD	Active	51.2 %	48.8 %	0.0 %	0.0 %	0.0 %	0.0 %

Net Savings Factors

Measures

MTCSAPVP	Maple Sap Vacum Pump VFD

Tracks [Base Track]

6013CUST [is base track]	Cust Equip Rpl
6013PRES [is base track]	Pres Equip Rpl

Persistence

The persistence factor is assumed to be one.

Lifetimes

15 years.

Measure Cost

$159/HP[2]

O&M Cost Adjustments

There are no standard operation and maintenance cost adjustments used for this measure.

Fossil Fuel Description

There are no fossil-fuel algorithms or default savings for this measure.

Prescriptive Savings Table

Horsepower	Prescriptive Energy Savings (kWh)	Prescriptive Connected Load Reduction (kW)	Incremental Costs ($)
7.5	1,163	0.90	$1,193
10	1,550	1.20	$1,590
15	2,325	1.80	$2,385
20	3,100	2.40	$3,180
25	3,875	3.00	$3,975

Footnotes

[1] Assumes that there will be ~50% more Rx measures per year than the average number of custom measures per year in 2010 and 2011, see Maple Sap VFD_Analysis.xls

[2] Derived from Efficiency Vermont custom data 2010-2011, see Maple Sap VFD_Analysis.xls

Variable Frequency Drives (VFD)

Measure Number:	I-A-2 d
Portfolio:	92
Status:	Active
Effective Date:	2016/1/1
End Date:	[None]
Program:	Business Energy Services
End Use:	Motors

Update Summary

- Measure updated to expand technology offering from <= 10 HP to <=100 HP for select applications
- Measure updated to utilize the Cadmus VFD Loadshape Research Study
- Measure updated to utilize more recent Measure Costs

Referenced Documents

- Navigant Consulting. (2013, January 16). Incremental Cost Study Phase Two Final Report.
- Efficiency Vermont 2016 VFD Loadshapes and Costs
- Cadmus. (2014). Variable Speed Drive Loadshape Project. Lexington: NEEP Regional Evaluation, Measurement and Verification Forum

Description

This measure characterization presents standardized savings algorithms and assumptions for VFDs applied to motors of 100 HP or less for the following HVAC applications: supply fans, return fans, cooling water pumps, circulation pumps for water source heat pump systems, and heating hot water pumps ("Standardized Approach"). Standardized savings algorithms and assumptions of up to 10 HP for boiler draft fans and cooling tower fans are also applicable. All other VFDs are treated as custom measures.

The calculations for most of the applications rely heavily on a study conducted on behalf of the Northeast Energy Efficiency Partnerships (NEEP) Evaluation, Measurement, and Verification Forum (EM&V Forum), which conducts research studies to support energy-efficiency programs and policy in the Northeast and Mid-Atlantic states. In 2012, the EM&V Forum and its Sponsors commissioned this Variable Speed Drive (VSD) Loadshape study to determine the hourly energy and demand impacts of variable speed drives installed on HVAC equipment in existing nonresidential buildings throughout the Northeast and Mid-Atlantic.

Between 2013 and 2014, Cadmus and DMI (the evaluation team) worked with the EM&V Forum's Technical Committee to complete this study. The referenced report (Cadmus 2014) describes the study objective, methods, and results. The attached spreadsheet (NEEP 2016 provides more details on the data and the calculations.

Baseline Efficiencies

The baseline operation for supply fans, return fans, hot water pumps, cooling water pumps, and WSHP circulation pumps are described extensively in (Cadmus, 2014).[1] Sections 3.1, 3.2, and 3.3 of that document summarize how the baseline motors were being operated, while the methods of developing the baseline for modeling are described in detail in Section 2.4.4. The baseline includes a wide variety of operating conditions, including motors with continuous operation and very low (or no) operating hours, and both non-seasonal and seasonal systems. "Cooling water pumps" include both chilled water pumps and condenser water pumps. "Heating hot water pumps" refers to pumps that serve space heating loads, which may also serve DHW loads, as well as pumps that operate as hot water pumps for the heating season and cooling water pumps for the cooling season; it does not include DHW-only pumps.

For boiler draft fans, the baseline is assumed to be a draft fan with no VFD, while for cooling towers, the baseline reflects a tower fan with discharge damper controls.[2]

Efficient Equipment

The high efficiency case is installation and use of a VFD.

Algorithms

Electric Demand Savings

ΔkW	$= DSVG \times HP \times OTF$

Symbol Table

Electric Energy Savings

ΔkWh	$= ESVG \times HP \times OTF$

Symbol Table

Fossil Fuel Savings

Where:

ΔkW = gross kW connected load reductions for the measure, representing the average kW savings at either the summer or winter coincidence period (whichever is greater); see also Tables 4-6 below for prescriptive kW reduction values for each combination of horsepower and application

ΔkWh = gross customer annual kWh savings for the measure; see also Table 3 below for prescriptive kWh savings values for each combination of horsepower and application

DSVG = demand savings factor, calculated as the maximum of the summer and winter demand savings factors; see Table 1 below (kW/HP)

ESVG = energy savings factor; see Table 1 below (kWh/HP)

HP = horsepower of the motor to which the VFD is applied

kWh = gross customer annual kWh savings for the measure; see also Table 3 below for prescriptive kWh savings values for each combination of horsepower and application

OTF = operational testing factor for standard approach applications. OTF = 1.00 when the project undergoes operational testing or commissioning services, OTF = 0.9 otherwise. For prescriptive rebate form applications the OTF will be assumed to be 0.9.

Load Shapes

102a VFD - Boiler draft fans <10 HP
103a VFD - Cooling Tower Fans <10 HP
117a VFD WSHP Circulation Pumps - Prescriptive <=100 HP
55c VFD Supply Fans - Prescriptive <=100 HP
56c VFD Return Fans - Prescriptive <=100 HP
59c VFD Cooling Water Pumps - Prescriptive <=100 HP
76c VFD Heating Hot Water Pumps - Prescriptive <=100 HP

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
102	VFD - Boiler draft fans <10 HP	Active	45.8 %	53.1 %	0.7 %	0.4 %	40.0 %	0.0 %
103	VFD - Cooling Tower Fans <10 HP	Active	10.1 %	5.0 %	58.6 %	26.3 %	0.0 %	61.6 %
117	VFD WSHP Circulation Pumps - Prescriptive <=100 HP	Active	45.5 %	23.1 %	20.3 %	11.1 %	100.0 %	77.1 %
55	VFD Supply Fans - Prescriptive <=100 HP	Active	48.3 %	18.5 %	24.0 %	9.2 %	92.0 %	100.0 %
56	VFD Return Fans - Prescriptive <=100 HP	Active	53.6 %	13.5 %	26.2 %	6.7 %	90.7 %	100.0 %
59	VFD Cooling Water Pumps - Prescriptive <=100 HP	Active	45.5 %	21.5 %	22.2 %	10.8 %	100.0 %	94.3 %
76	VFD Heating Hot Water Pumps - Prescriptive <=100 HP	Active	35.8 %	17.7 %	8.0 %	38.5 %	100.0 %	43.4 %

Net Savings Factors

Measures

MTCSTVFD	Variable frequency drive, standardized
MTCVFDSF	Variable frequency drive, standardized HVAC – Supply Fans
MTCVFDRF	Variable frequency drive, standardized HVAC – Return Fans
MTCVFDCP	Variable frequency drive, standardized HVAC – Cooling Water Pumps
MTCVFDHP	Variable frequency drive, standardized HVAC – Heating Hot Water Pumps
MTCVFDBF	Variable frequency drive, standardized HVAC – Boiler Draft Fans
MTCVFDWP	Variable frequency drive, standardized HVAC – WSHP Circulation Pumps
MTCVFDCF	Variable frequency drive, standardized HVAC – Cooling Tower Fans

Tracks [Base Track]

6012CNIR [is base track]	C&I Retro
6013PRES [is base track]	Pres Equip Rpl

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
C&I Retro	6012CNIR	MTCSTVFD	0.89	1.00
Pres Equip Rpl	6013PRES	MTCSTVFD	0.95	1.00
Pres Equip Rpl	6013PRES	MTCVFDSF	0.95	1.00
Pres Equip Rpl	6013PRES	MTCVFDRF	0.95	1.00
Pres Equip Rpl	6013PRES	MTCVFDCP	0.95	1.00
Pres Equip Rpl	6013PRES	MTCVFDHP	0.95	1.00
Pres Equip Rpl	6013PRES	MTCVFDBF	0.95	1.00

Pres Equip Rpl	6013PRES	MTCVFDWP	0.95	1.00
Pres Equip Rpl	6013PRES	MTCVFDCF	0.95	1.00

Lifetimes

The measure life is assumed to be 15 years for HVAC applications.

Measure Cost

Because this is a retrofit measure, the cost is assumed to be the full installed cost of a VFD, and varies by controlled motor horsepower. See Table 2 “VFD Measure Costs” below.

Reference Tables

Table 1. Annual Energy and Demand Savings per Unit Horsepower Equipment Type[3]

	ESVG	**DSVG**[4]	**$DSVG_{winter}$**	**$DSVG_{summer}$**
	kWh/hp	kW/hp	kW/hp	kW/hp
Supply Fans	2,033	0.288	0.265	0.288
Return Fans	1,788	0.302	0.274	0.302
Cooling Water Pumps	1,633	0.194	0.194	0.183
Heating Hot Water Pumps	1,548	0.221	0.221	0.096
WSHP Circulation Pumps	2,562	0.297	0.297	0.229
Boiler Draft Fans	500	0.270	0.108	0.0
Cooling Tower Fans	239	0.280	0.0	0.17248

Table 2. Variable Frequency Drive (VFD) Costs[5]

Horsepower	Equipment Cost	Labor Cost	Total Installed Cost
2	$779	$780	$1,559
3	$883	$780	$1,663
5	$1,092	$780	$1,872
7.5	$1,353	$780	$2,133
10	$1,615	$780	$2,395
15	$2,137	$780	$2,917
20	$2,660	$780	$3,440
25	$3,182	$780	$3,962
30	$3,610	$780	$4,390
40	$4,467	$780	$5,247
50	$5,324	$780	$6,104
60	$6,091	$780	$6,871
75	$7,242	$780	$8,022
100	$8,662	$780	$9,442

Table 3. Prescriptive Energy Savings (kWh)

Horsepower	Supply Fans	Return Fans	Cooling Water Pumps	Heating Hot Water Pumps	WSHP Circulation Pumps	Boiler Draft Fans	Cooling Tower Fans
2	3,659.4	3,218.4	2,939.4	2,786.4	4,611.6	900.0	430.2
3	5,489.1	4,827.6	4,409.1	4,179.6	6,917.4	1,350.0	645.3
5	9,148.5	8,046.0	7,348.5	6,966.0	11,529.0	2,250.0	1,075.5
7.5	13,722.8	12,069.0	11,022.8	10,449.0	17,293.5	3,375.0	1,613.3
10	18,297.0	16,092.0	14,697.0	13,932.0	23,058.0	4,500.0	2,151.0
15	27,445.5	24,138.0	22,045.5	20,898.0	34,587.0	NA	NA
20	36,594.0	32,184.0	29,394.0	27,864.0	46,116.0	NA	NA
25	45,742.5	40,230.0	36,742.5	34,830.0	57,645.0	NA	NA

30	54,891.0	48,276.0	44,091.0	41,796.0	69,174.0	NA	NA
40	73,188.0	64,368.0	58,788.0	55,728.0	92,232.0	NA	NA
50	91,485.0	80,460.0	73,485.0	69,660.0	115,290.0	NA	NA
60	109,782.0	96,552.0	88,182.0	83,592.0	138,348.0	NA	NA
75	137,227.5	120,690.0	110,227.5	104,490.0	172,935.0	NA	NA
100	182,970.0	160,920.0	146,970.0	139,320.0	230,580.0	NA	NA

Table 4. Prescriptive Connected Load Reduction (kW)

Horsepower	Supply Fans	Return Fans	Cooling Water Pumps	Heating Hot Water Pumps	WSHP Circulation Pumps	Boiler Draft Fans	Cooling Tower Fans
2	0.51840	0.54360	0.34920	0.39780	0.53460	0.48600	0.50400
3	0.77760	0.81540	0.52380	0.59670	0.80190	0.72900	0.75600
5	1.29600	1.35900	0.87300	0.99450	1.33650	1.21500	1.26000
7.5	1.94400	2.03850	1.30950	1.49175	2.00475	1.82250	1.89000
10	2.59200	2.71800	1.74600	1.98900	2.67300	2.43000	2.52000
15	3.88800	4.07700	2.61900	2.98350	4.00950	NA	NA
20	5.18400	5.43600	3.49200	3.97800	5.34600	NA	NA
25	6.48000	6.79500	4.36500	4.97250	6.68250	NA	NA
30	7.77600	8.15400	5.23800	5.96700	8.01900	NA	NA
40	10.36800	10.87200	6.98400	7.95600	10.69200	NA	NA
50	12.96000	13.59000	8.73000	9.94500	13.36500	NA	NA
60	15.55200	16.30800	10.47600	11.93400	16.03800	NA	NA
75	19.44000	20.38500	13.09500	14.91750	20.04750	NA	NA
100	25.92000	27.18000	17.46000	19.89000	26.73000	NA	NA

Table 5. Prescriptive Winter Coincident Demand Reduction (kW)

Horsepower	Supply Fans	Return Fans	Cooling Water Pumps	Heating Hot Water Pumps	WSHP Circulation Pumps	Boiler Draft Fans	Cooling Tower Fans
2	0.47700	0.49320	0.34920	0.39780	0.53460	0.19440	0.00
3	0.71550	0.73980	0.52380	0.59670	0.80190	0.29160	0.00
5	1.19250	1.23300	0.87300	0.99450	1.33650	0.48600	0.00
7.5	1.78875	1.84950	1.30950	1.49175	2.00475	0.72900	0.00
10	2.38500	2.46600	1.74600	1.98900	2.67300	0.97200	0.00
15	3.57750	3.69900	2.61900	2.98350	4.00950	NA	NA
20	4.77000	4.93200	3.49200	3.97800	5.34600	NA	NA
25	5.96250	6.16500	4.36500	4.97250	6.68250	NA	NA
30	7.15500	7.39800	5.23800	5.96700	8.01900	NA	NA
40	9.54000	9.86400	6.98400	7.95600	10.69200	NA	NA
50	11.92500	12.33000	8.73000	9.94500	13.36500	NA	NA
60	14.31000	14.79600	10.47600	11.93400	16.03800	NA	NA
75	17.88750	18.49500	13.09500	14.91750	20.04750	NA	NA
100	23.85000	24.66000	17.46000	19.89000	26.73000	NA	NA

Table 6. Prescriptive Summer Coincident Demand Reduction (kW)

Horsepower	Supply Fans	Return Fans	Cooling Water Pumps	Heating Hot Water Pumps	WSHP Circulation Pumps	Boiler Draft Fans	Cooling Tower Fans
2	0.51840	0.54360	0.32940	0.17280	0.41220	0.00	0.31046
3	0.77760	0.81540	0.49410	0.25920	0.61830	0.00	0.46570
5	1.29600	1.35900	0.82350	0.43200	1.03050	0.00	0.77616
7.5	1.94400	2.03850	1.23525	0.64800	1.54575	0.00	1.16424

10	2.59200	2.71800	1.64700	0.86400	2.06100	0.00	1.55232
15	3.88800	4.07700	2.47050	1.29600	3.09150	NA	NA
20	5.18400	5.43600	3.29400	1.72800	4.12200	NA	NA
25	6.48000	6.79500	4.11750	2.16000	5.15250	NA	NA
30	7.77600	8.15400	4.94100	2.59200	6.18300	NA	NA
40	10.36800	10.87200	6.58800	3.45600	8.24400	NA	NA
50	12.96000	13.59000	8.23500	4.32000	10.30500	NA	NA
60	15.55200	16.30800	9.88200	5.18400	12.36600	NA	NA
75	19.44000	20.38500	12.35250	6.48000	15.45750	NA	NA
100	25.92000	27.18000	16.47000	8.64000	20.61000	NA	NA

Footnotes

[1] (Cadmus, 2014), Sections 2.4.4 Hourly Baseline Operating Power (pp. 38-43); 3.1 Final Study Sample (p.51); 3.2 Observations on VSD Operation (pp. 51-55); 3.3 Pre-Retrofit Operation (pp. 55-57).

[2] (Efficiency Vermont, 2011), Overview; Summary.

[3] Savings factors for Supply Fans, Return Fans, Cooling Water Pumps, Heating Hot Water Pumps, and WSHP Circulation Pumps from (Cadmus, 2014), Table 6 Annual Energy Savings per Unit Horsepower (p. xiv) and Table 7 ISO-NE Summer and Winter On-Peak Demand Savings per Unit Horsepower (p. xiv). Savings factors for Boiler Draft Fans and Cooling Tower Fans from (Efficiency Vermont, 2011), Summary worksheet. The Efficiency Vermont savings analysis is based on Equest modeling performed by Efficiency Vermont. For boiler draft fans the factors are based on an analysis of office applications, while for cooling tower fans the factors are based on an average of the results of analyses for office and school applications.

[4] The DSVG represents the maximum of the summer and winter demand savings factors identified in the source analyses. The summer and winter DSVG may be derived by multiplying the DSVG by the respective coincidence factors from the designated loadshapes for each application.

[5] Equipment and labor costs from (Navigant Consulting, 2013), Table A10 VFD Incremental Costs (p.118), extrapolated or interpolated as necessary for motor sizes not covered in the Navigant Report. See (Efficiency Vermont, 2016), Costs worksheet.

Efficient Milk Pumping Systems for Dairy Farms

Measure Number:	I-A-5 c
Portfolio:	77
Status:	Active
Effective Date:	2012/1/1
End Date:	[None]
Program:	Business Energy Services
End Use:	Motors

Referenced Documents

- Dairy_VFD_Analysis

Description

A variable speed milk transfer (VSMT) pump is a VFD regulated pump that allows operators to to increase the efficiency of a plate heat exchanger by making the flow of milk slower and more consistent to maximize heat transfer within the heat exchanger. Electrical savings occurs "downstream" by reducing the load on the chiller in the milk storage tank and is adjusted for the increased load due to adding the pump itself to the system. A VSMT is typically an add-on to an existing system or replaces old equipment when it reaches the end of its useful life.

A milk vacuum pump is used to move milk between the milking area and bulk storage. A VFD equipped milk vacuum pump is used to reduce pump speed, and energy consumption, when pumping needs fall below peak levels. Electricity is saved relative to a system that pumps at a constant rate. A VFD milk vacuum pump typically replaces old equipment when it reaches the end of its useful life.

Estimated Measure Impacts

	Average Annual MWH Savings per unit	Average number of measures per year	Average Annual MWH savings per year
Variable Speed Milk Transfer Pump	8.6	4	34.6
Milk Vacuum Pump VFD	7.8	23	179.3

Algorithms

Variable Speed Milk Transfer Pump Electric Demand Savings

$\Delta kW = 2.73\ kW$

Symbol Table

Variable Speed Milk Transfer Pump Electric Energy Savings

$\Delta kWh = 7{,}687\ kWh$

Symbol Table

Milk Vacuum Pump VFD Electric Demand Savings

$\Delta kW = 3.01\ kW$

Symbol Table

Milk Vacuum Pump VFD Electric Energy Savings

$\Delta kWh = 7{,}769\ kWh$

Where:

ΔkW = gross customer connected load kW savings for the measure

ΔkWh = gross customer average annual kWh savings for the measure

Savings estimates are the average savings claimed for EVT custom projects from 2003 through 2011, see Dairy_VFD_Analysis.xls

Baseline Efficiencies

VSMT: the baseline state is no regulation of milk flow rate to the plate cooler.

Milk vacuum pump VFD: the baseline state is a non-VFD equipped pump.

While these technologies would be baseline for new construction, farmers typically re-use old equipment when extensively renovating old facilities. New construction due to construction of new facilities is rare and EVT staff has only heard of one case (between 2006 and 2012) where a new construction project resulted in purchase of new equipment.

High Efficiency

A variable speed milk transfer pump regulates flow to optimize the performance of a plate cooler.

A VFD equipped milk vacuum pump reduces pump speed when pumping needs fall below peak levels.

Operating Hours

N/A

Load Shapes

Load shapes were developed based on actual data for EVT custom projects installed through the EVT dairy farm program from 2008 through 2011, see Dairy_VFD_Analysis.xls The variable speed milk transfer pump load profile is the same as the "Dairy Plate Cooler / Heat Recovery Unit," which is based on 112 plate cooler and heat recovery unit projects. The milk vacuum pump load profile is based on 94 projects.

61b Milk Vacuum Pump
111a Farm Plate Cooler / Heat Recovery Unit

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
61	Milk Vacuum Pump	Active	36.9 %	30.1 %	18.2 %	14.8 %	63.4 %	28.7 %
111	Farm Plate Cooler / Heat Recovery Unit	Active	29.0 %	16.4 %	31.6 %	23.1 %	27.0 %	16.1 %

Net Savings Factors

Measures

MTCDFVFD	Dairy Milk Pump VFD
MTCMTVFD	Variable Speed Milk Transfer Pump

Tracks [Base Track]

6013CUST [is base track]	Cust Equip Rpl
6013PRES [is base track]	Pres Equip Rpl

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Cust Equip Rpl	6013CUST	MTCDFVFD	0.94	1.00
Cust Equip Rpl	6013CUST	MTCMTVFD	0.94	1.00
Pres Equip Rpl	6013PRES	MTCDFVFD	1.00	1.00
Pres Equip Rpl	6013PRES	MTCMTVFD	1.00	1.00

Persistence

The persistence factor is assumed to be one.[1]

Lifetimes

10 years.

Measure Cost

Variable speed milk transfer pump:	$3,004[2]
Milk vacuum pump VFD:	$4,014[2]

O&M Cost Adjustments

There are no standard operation and maintenance cost adjustments used for this measure.

Fossil Fuel Description

There are no fossil fuel algorithms or default values for this measure.

Footnotes

[1] National Grid evaluated persistence in 1999 of VFDs installed in 1995 and estimated a factor of 97%. Given that the discounted value of a 3% degradation in 5 years is minimal, no persistence reduction has been applied.

[2] Values derived from Efficiency Vermont custom data 2003-2012, see Dairy_VFD_Analysis.xls

Commercial Brushless Permanent Magnet (BLPM) Fan Motor

Measure Number:	I-A-6 c
Portfolio:	94
Status:	Active
Effective Date:	2017/1/1
End Date:	[None]
Program:	Business Energy Services
End Use:	Motors

Update Summary

Updates to the measure include the following:

- All references were determined to be out-of-date and have been updated with more recent studies, resources, and savings spreadsheets.
- Energy/Demand Algorithms have been updated to include a bonus factor to account for additional kWh savings for cooling due to less heat loss of efficient fans.
- Deemed values and savings calculations have been updated to reflect updated references.

Referenced Documents

- Commercial Furnace Fan Motor Savings
- Navigant, “Energy Savings Potential and Opportunities for High-Efficiency Electric Motors in Residential and Commercial Equipment”, 2013.
- DEER2014-EUL-table-update_2014-02-05.xlsx
- Commercial BLPM Fan Motor Savings.xlsx
- NREL, “Evaluation of Retrofit Variable-Speed Furnace Fan Motors”, 2014.
- NEEP HVAC Load Shape Report_ Final_August2
- New York Standard Approach for Estimating Energy Savigns from Energy Efficiency Programs 2016

Description

This measure will provide incentives for installing an ultra high efficiency programmable brushless permanent magnet fan motor called Brushless Permanent Magnet Motor (BLPM, sometimes referred to as ECM, ICM, or brushless DC motor), hereafter referred to as “BLPM fan motor.” The incentive offer and savings estimation relate only to the efficiency gains associated with an upgrade to a BLPM fan motor, rather than for improvements in the efficiency of the heating and cooling equipment. That is, increases in AFUE or EER/SEER are NOT covered by this measure. The installation of a BLPM fan motor for businesses can apply to: just the heating system (heating only), just the central A/C system (cooling only), or for an air handler servings both heating and cooling systems (heating and cooling).

Estimated Measure Impacts

Algorithms

Demand Savings

ΔkW $= ((Watts_{Base} - Watts_{EE}) / 1000) \times BF$

Symbol Table

Energy Savings

ΔkWh $= ((Watts_{Base} - Watts_{EE}) / 1000) \times (Hours_{Heating} + Hours_{Cooling} \times BF)$

Where:

ΔkW	=	Maximum customer kW savings
ΔkWh	=	Gross customer annual kWh savings
1000	=	Convert watts to kilowatts
BF	=	Bonus Factor to account for reduced waste heat of baseline motor. 1.3 for Cooling; 1.0 for Heating Only applications.[1]
$Hours_{Cooling}$	=	Hours of fan operation for Cooling application. 755 hours[4]; Cooling hours are 0 for Heating Only applications
$Hours_{Heating}$	=	Hours of fan operation for Heating application.

1238 hours[5]; Heating hours are 0 for Cooling Only applications.

$Watts_{Base}$ = Power consumption of baseline fan motor. 571 Watts.[2]

$Watts_{EE}$ = Power consumption of energy efficient fan motor. 392 Watts.[3]

Average Savings for BLPM Commercial HVAC Fan Motors

Application	kWh savings	kW savings
Heating Only	222	0.179
Cooling Only	181	0.240
Heating and Cooling	403	0.240

Baseline Efficiencies

A low-efficiency permanent split capacitor (PSC) fan motor on a hot air furnace, split system air conditioner, or a combined air handling system serving both heating and cooling.

High Efficiency

A brushless permanent magnet motor (BLPM, also called ECM, ICM, and other terms) on a hot air furnace, split system air conditioner, or a combined air handling system serving both heating and cooling.

Operating Hours

Heating: 1238 hours/year.[5]

Cooling: 755 hours/year.[4]

Load Shapes

See derivation of the savings profiles in “Commercial Furnace Fan Motor Savings.xls”.

78c BLPM Fan Motor Commercial Heating
79c BLPM Fan Motor Commercial Cooling
80c BLPM Fan Motor Commercial Heating & Cooling

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
78	BLPM Fan Motor Commercial Heating	Active	34.4 %	56.1 %	4.5 %	5.0 %	50.2 %	19.0 %
79	BLPM Fan Motor Commercial Cooling	Active	18.3 %	0.4 %	67.4 %	13.9 %	0.0 %	80.1 %
80	BLPM Fan Motor Commercial Heating & Cooling	Active	30.9 %	42.2 %	19.1 %	7.8 %	50.2 %	52.4 %

Net Savings Factors

Measures

SHEFNMTR	Furnace fan motor

Tracks [Base Track]

6012CNIR [is base track]	C&I Retro
6013CUST [is base track]	Cust Equip Rpl
6013PRES [is base track]	Pres Equip Rpl
6018LINC [is base track]	LIMF NC
6019MFNC [is base track]	MF Mkt NC

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
C&I Retro	6012CNIR	SHEFNMTR	1.00	1.00
Cust Equip Rpl	6013CUST	SHEFNMTR	1.00	1.00
Pres Equip Rpl	6013PRES	SHEFNMTR	1.00	1.00
LIMF NC	6018LINC	SHEFNMTR	1.00	1.00
MF Mkt NC	6019MFNC	SHEFNMTR	1.00	1.00

Persistence

The persistence factor is assumed to be one.

Lifetimes

15 years.[6]

Measure Cost

$180 for Market Opportunity[7]

O&M Cost Adjustments

There are no operation and maintenance cost adjustments for this measure.

Fossil Fuel Description

There is an increase in fossil fuel use associated with this measure, due to the decrease in waste heat produced by the BLPM motor during the heating season.

ΔMMBtu = 0.5[8] for Heating Only, as well as Heating and Cooling

ΔMMBtu = 0.0 for Cooling Only

Incentive Level

Footnotes

[1] Bonus Factors derived from the difference in total savings of the efficient motor and the calculated savings based on motor demands and operating hours. NREL, "Technical Report: Evaluation of Retrofit Variable-Speed Furnace Fan Motors", 2014. Page 18, Table 8. For bonus factor calculation see reference file "Commercial BLPM Fan Motor Savings.xls".

[2] Average baseline motor demand derived from results of NREL, "Technical Report: Evaluation of Retrofit Variable-Speed Furnace Fan Motors", 2014. Page 12, Tables 3 and 4. For calculation see reference file "Commercial BLPM Fan Motor Savings.xlsx".

[3] Average efficient motor demand derived from results of NREL, "Technical Report: Evaluation of Retrofit Variable-Speed Furnace Fan Motors", 2014. Page 12, Tables 3 and 4. For calculation see reference file "Commercial BLPM Fan Motor Savings.xlsx".

[4] EFLH for commercial air conditioning are derived directly from the following KEMA report. KEMA, "C&I Unitary HVAC Load Shape Project Final Report", Northeast Energy Efficiency Partnerships, Regional Evaluation, Measurement, and Verification Forum, August 2, 2011. Pg. 57, Table 3-1.

[5] Equivalent full load heating hours were derived from New York reported EFLH for small commercial heating applications. Hours were adjusted using TMY3 data for Vermont and New York. See reference file "Commercial BLPM Fan Motor Savings.xlsx", 'EFLH_Heating' Tab. New York EFLH hours are referenced from New York State Joint Utilities, "New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs", Version 4, April 2016. Pg. 444, Appendix G - Small Commercial Heating EFLH.

[6] Effective Useful Life as determined in the 2014 update of the DEER Database. See reference file "DEER 2014 EUL Table Update.xlsx"

[7] Costs are based on the market opportunity of a BLPM motor on a new furnace. Navigant Consulting, "Energy Savings Potential and Opportunities for High-Efficiency Electric Motors in Residential and Commercial Equipment", 2013. Page 28, Table 3.6.

[8] See calculation in "Commercial BLPM Fan Motor Savings.xls," based on waste heat reduction of fan motor resulting in an increase in heating load. Results from NREL study were adjusted based on Vermont operating hours. NREL, "Technical Report: Evaluation of Retrofit Variable-Speed Furnace Fan Motors", 2014. Pages 16-17, Tables 6-7.

Brushless Permanent Magnet (BLPM) Circulator Pump

Measure Number: I-A-7 b
Portfolio: 96
Status: Active
Effective Date: 2017/1/1
End Date: [None]
Program: Business Energy Services
End Use: Motors

Update Summary

- The measure has been updated to replace a list of manufacturer pump data with more recent circulator pump studies and pump motor efficiency data

Referenced Documents

- Navigant, “Energy Savings Potential and Opportunities for High-Efficiency Electric Motors in Residential and Commercial Equipment”, 2013.
- Commercial BLPM Pump Motor Analysis.xlsx
- EPRI, "Assessment of New Energy Efficient Circulator Pump Technology", 2010.
- EPRI, "Assessment of New Motor Technologies and their Applications", 2013.

Description

This measure is for installing circulator pumps with brushless permanent magnet pump (BLPM) motors, less than or equal to three horsepower. Typical applications include baseboard and radiant floor heating systems that utilize a primary/secondary loop system in multifamily residences and small commercial buildings. This measure is restricted to systems that use high mass boilers (>300,000 Btu/h) where the primary loop circulator runs constantly during the heating season. Circulator pumps that use BLPMs are more efficient because they lack brushes that add friction to the motor, as well as the ability to modulate their speed to match the load. This is possible because the drive senses the difference between the magnetic field of the rotating rotor and the rotating magnetic field of the windings in the motor stator. As the system flow demand changes (zones open or close), the drive senses the torque difference at the impeller via the change in the magnetic field difference and adjusts its speed by altering the frequency to the motor. BLPMs are especially efficient in no-load/low-load applications.

Baseline Efficiencies

The baseline equipment is a circulator pump using a low-efficiency induction motor. It is assumed that this pump is installed on the primary loop of a multi-loop system, and is running constantly when outside temperatures are 55°F or lower during the winter heating season (October – April).

Efficient Equipment

The efficient equipment is a circulator pump with brushless permanent magnet motor.

Algorithms

Electric Demand Savings

ΔkW $= (Watts_{Base} - Watts_{Eff}) / 1000$

Demand Savings for Commercial BLPM Pump Motors[1]

Where W_{MAX} = Maximum rated wattage of efficient circulator pump (nameplate information)

Maximum Rated Watts (BLPM Motor)	Average Rated Watts for BLPM Pump Motor[2]	Average Watts for Baseline Pump Motor[3]	Average Demand Savings ΔkW
$W_{MAX} \leq 144$	74	141	0.0675
$144 < W_{MAX} \leq 575$	276	371	0.0953
$575 < W_{MAX} \leq 2500$	1082	1209	0.1270

Symbol Table

Electric Energy Savings

ΔkWh $= (Watts_{Base} - Watts_{Eff} \times (1 - Control)) / 1000 \times Hours$

Energy Savings for Commercial BLPM Pump Motors[1]

Where W_{MAX} = Maximum rated wattage of efficient circulator pump (nameplate information)

Maximum Rated Watts	Average Annual Energy Savings

(BLPM Motor)	Energy Savings ΔkWh
$W_{MAX} \leq 144$	401.3
$144 < W_{MAX} \leq 575$	780.1
$575 < W_{MAX} \leq 2500$	1924.3

Symbol Table

Fossil Fuel Savings

Where:

ΔkW = Gross customer connected load kW savings for the measure (kW). Savings calculated by different bins of efficient wattages

ΔkWh = Gross customer annual kWh savings for the measure (kWh)

1000 = Conversion from watts to kilowatts

Control = Control factor accounts for additional savings due to reduced power operation and control functions utilized with BLPM pump motor; 0.27.[4]

Hours = Annual operating hours during heating season; 4592 hours.[5]

$Watts_{Base}$ = Watt rating of baseline induction motor. Baseline rating is estimated based on rating of efficient motor replacement

$Watts_{Eff}$ = Maximum Watt rating of efficient BLPM motor. Refer to Demand Savings table below for motor size bins

Operating Hours

The annual operating hours are assumed to be 4592[5]

Load Shapes

17a Commercial Space heat

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
17	Commercial Space heat	Active	38.7 %	61.2 %	0.0 %	0.1 %	57.0 %	0.3 %

Net Savings Factors

Measures

SHECPMTR	BLPM Circulator Pump

Tracks [Base Track]

6013UPST [is base track]	Upstream - Commercial

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Upstream - Commercial	6013UPST	SHECPMTR	0.95	1.00

Persistence

The persistence factor is assumed to be 1.

Lifetimes

20 years – typical circulator pumps using low-efficiency induction motors are expected to last around 15 years; circulator pump motors with BLPMs typically operate at lower RPMs, thus producing less heat and extending the life of the motor.

Measure Cost

The estimated full cost for this measure varies based on the size of the motor. See the table below for further details.

Cost for Commercial BLPM Pump Motors[6]

Where W_{MAX} = Maximum rated wattage of efficient circulator pump (nameplate information)

Maximum Rated Watts (BLPM Motor)	Average Cost (incl. Labor)
$W_{MAX} \leq 144$	$547
$144 < W_{MAX} \leq 575$	$1,643
$575 < W_{MAX} \leq 2500$	$3,316

O&M Cost Adjustments

None.

Water Descriptions

None.

Footnotes

[1] For pump savings analysis see reference file "Commercial BLPM Pump Motor Analysis.xlsx"

[2] Average wattages determined from list of EVT qualified pump models as of December 2016. For details see reference file "Commercial BLPM Pump Motor Analysis.xlsx".

[3] Average baseline wattages are calculated using motor efficiency curves and the average wattages of efficient BLPM motors. For calculations see reference file "Commercial BLPM Pump Motor Analysis.xlsx". Efficiencies developed from the following sources. U.S. DOE, "Premium Efficiency Motor Selection and Application Guide", 2014; Navigant, "Energy Saving Potential and Opportunities for High-Efficiency Electric Motors in Residential and Commercial Equipment" provided to the U.S. DOE, 2013.

[4] The control factor is derived using motor efficiency curves and the results of the following EPRI studies to account for additional savings from operating control modes of efficient BLPM motors; EPRI, "Assessment of New Motor Technologies and their Applications", 2013. EPRI, "Assessment of New Energy Efficient Circulator Pump Technology", 2010. For details see reference file "Commercial BLPM Pump Motor Analysis.xlsx".

[5] Operating hours are calculated as the total hours between the months of October 1st and April 30th where the outside air dry-bulb temperature is below 55°. Hours are an average number of heating season hours from 2012 through 2015. See reference file "Commercial BLPM Pump Motor Analysis.xlsx".

[6] For costs analysis see reference file "Commercial BLPM Pump Motor Analysis.xlsx"

Door Heater Controls

Measure Number: I-E-10 d
Portfolio: 93
Status: Active
Effective Date: 2017/1/1
End Date: [None]
Program: Business Energy Services
End Use: Refrigeration

Update Summary

- Measure updated to evaluate only humidity based door heater controls
- Measure updated to utilize the Cadmus Commercial Refrigeration Loadshape report
- Measure updated to utilize more recent Measure Cost and electrical characteristics of door heaters

Referenced Documents

- United States Department of Energy 10 CFR Part 431, Docket No. EERE-2010-BT-STD-0003, 2010
- Anti-Sweat Door Heater Controls NEEP ICS4 Final June 23 2015
- The Cadmus Group, Commercial Refrigeration Loadshape Project Final Report, Northeast Energy Efficiency Partnerships, Regional Evaluation, Measurement, and Verification Forum, Lexington, MA 2015.
- Door Heater Control Study 2016 v2.xls

Description

Another option to zero-energy doors – that is also effective on existing reach-in cooler or freezer doors – is “on-off” control of the operation of the door heaters. Because relative humidity levels differ greatly across the United States, a door heater in Vermont needs to operate for a much shorter season than a door heater in Florida. By installing a control device to turn off door heaters when there is little or no risk of condensation, one can realize energy and cost savings.

There are two strategies for this control, based on either (1) the relative humidity of the air in the store or (2) the “conductivity” of the door (which drops when condensation appears). In the first strategy, the system activates your door heaters when the relative humidity in your store rises above a specific setpoint, and turns them off when the relative humidity falls below that setpoint. In the second strategy, the sensor activates the door heaters when the door conductivity falls below a certain setpoint, and turns them off when the conductivity rises above that setpoint.

Algorithms

Electric Demand Savings

$$\Delta kW = kW_{door} \times N_{door} \times ES \times BF$$

Symbol Table

Electric Energy Savings

$$\Delta kWh = \Delta kW \times 8760$$

Symbol Table

Fossil Fuel Savings

Where:

ΔkWh	=	Gross customer annual kWh savings for the measure (kWh)
ΔkW	=	Gross customer connected load kW savings for the measure (kW)
8760	=	Hours / Year
BF	=	Bonus factor for reduced cooling load from eliminating heat generated by the door heater from entering the cooler or freezer (1.3 for coolers, 1.5 for freezers)[1]
ES	=	Percent annual energy savings from off-time of heating elements (45.1% for coolers and freezers)[2]
kW_{door}	=	Connected load kW of a typical reach-in cooler or freezer door and frame with a heater (0.066 kW for Coolers, 0.230 kW for Freezers)[3]
N_{door}	=	Number of doors controlled by sensor

Baseline Efficiencies

The baseline condition is a cooler or freezer glass door that is continuously heated to prevent condensation.

Efficient Equipment

High efficiency is a cooler or freezer glass door with a humidity-based door-heater control.

Operating Hours

Door heaters operate 8760 hours per year.

Load Shapes

For Loadshape details, see reference: Door Heater Control Study 2016 v2.xls

69b Door Heater Control

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
69	Door Heater Control	Active	29.0 %	38.0 %	15.0 %	18.0 %	90.9 %	96.5 %

Net Savings Factors

Measures

RFRDRCON	Refrigeration door heater controls

Tracks [Base Track]

6013PRES [is base track]	Pres Equip Rpl
6014PRES [is base track]	6014PRES

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Pres Equip Rpl	6013PRES	RFRDRCON	1.00	1.00
6014PRES	6014PRES	RFRDRCON	0.95	1.05

Persistence

The persistence factor is assumed to be one.

Lifetimes

10 years[4]

Measure Cost

The cost for a refrigeration door heater control unit is $971. When evaluated on a per door basis costs are estimated at $121 per cooler door and $214 per freezer door.[5]

O&M Cost Adjustments

There are no standard operation and maintenance cost adjustments used for this measure.

Fossil Fuel Descriptions

There are no fossil fuel algorithms or default values for this measure.

Water Descriptions

There are no water algorithms or default values for this measure.

Reference Tables

There are no reference tables for this measure.

Footnotes

[1] Bonus factors as derived in the NEEP Refrigeration Loadshape Report. The Cadmus Group, *Commercial Refrigeration Loadshape Project Final Report*, Northeast Energy Efficiency Partnerships, Regional Evaluation, Measurement, and Verification Forum, Lexington, MA 2015. Page 78, Figure 54.

[2] Difference in effective runtime of an uncontrolled heater and all control style heater controls. Anti-sweat door heater control reduced run time. The Cadmus Group, *Commercial Refrigeration Loadshape Project Final Report*, Northeast Energy Efficiency Partnerships, Regional Evaluation, Measurement, and Verification Forum, Lexington, MA 2015. Page 69, Section 4.1.4, Table 37.

[3] Wattages per door derived from NEEP CRL report sample data. See reference file Door Heater Control Study 2016 v2.xls

[4] Measure lifetime is in reference to the United States federal energy standard for all commercial refrigeration equipment. United States Department of Energy 10 CFR Part 431, Docket No. EERE-2010-BT-STD-0003, 2010. Page 167, Section 7.

[5] Heater control unit costs were determined from the NEEP Incremental Cost Study Part 4 spreadsheet as listed for the New England region on a per controller and per door cost basis. See reference "Anti-Sweat Door Heater Controls NEEP ICS4 Final June 23 2015.xlsx", "Summary of Results" tab.

Floating Head Pressure Control

Measure Number: I-E-12 c
Portfolio: 96
Status: Active
Effective Date: 2017/1/1
End Date: [None]
Program: Business Energy Services
End Use: Refrigeration

Update Summary

- Measure is updated to replace savings deemed by manufacturer compressor listings with recent studies and savings for Floating Head Pressure Controls

Referenced Documents

The main analysis file used as the basis for this measure, RTF, "Commercial: Grocery - Floating Head Pressure Controls for Single Compressor Systems", workbook ComGroceryFHPCSingleCompressor_v1_5.xlsm, 2016 was developed for the Regional Technical Forum (RTF), a technical advisory committee to the Northwest Power and Conservation Council established in 1999 to develop standards to verify and evaluate energy efficiency savings by Portland Energy Conservation, Inc. (PECI).

The work was performed in support of a unitary condensing unit FHP measure developed by PECI for the RTF in 2010.

In attempt to contact PECI for further details about the work it was learned that the original authors no longer work in the same capacity, and furthermore, PECI is no longer responsible for the management of the refrigeration programs for which the workbook originally served.

- DEER2014-EUL-table-update_2014-02-05.xlsx
- RTF, "Commercial: Grocery - Floating Head Pressure Controls for Single Compressor Systems", workbook ComGroceryFHPCSingleCompressor_v1_5.xlsm, 2016
- FHP Savings Extrapolation.xlsx

Description

Installers conventionally design a refrigeration system to condense at a set pressure-temperature setpoint, typically 90 degrees. By installing a "floating head pressure control" condenser system, the refrigeration system can change condensing temperatures in response to different outdoor temperatures. This means that as the outdoor temperature drops, the compressor will not have to work as hard to reject heat from the cooler or freezer. This measure is for the application of floating head pressure controls for compressors ≤ 10HP and a condensing temperature set to 70ºF. This measure is strictly limited to single compressor systems.

Baseline Efficiencies

The baseline is a refrigeration system without floating head pressure control.

Efficient Equipment

High efficiency is a refrigeration system with floating head pressure control.

Algorithms

Electric Demand Savings

$$\Delta kW = \Delta kWh / HOURS$$

Symbol Table

Electric Energy Savings

$$\Delta kWh = kWh_{HP} \times HP$$

Floating Head Pressure Control kWh Savings per Horsepower (kWh/HP)[2]

Unit Type	Temperature Range		
	Low Temperature (Freezer)	Medium Temperature (Refrigerator)	Unknown Temperature[3]
Self-Contained Unit (SCU)	793	703	732
Remote Condensing Unit (RCU)	636	439	502
Unknown Type[4]	715	571	617

Symbol Table

Fossil Fuel Savings

Where:

ΔkW = Gross customer connected load kW savings for the measure (kW)

ΔkWh = Gross customer annual kWh savings for the measure (kWh)

HOURS = Full load hours (7713 hours)[1]

HP = Actual compressor horsepower.

kWh_{HP} = kWh per horsepower (value from savings table in Reference Tables section)

Operating Hours

Operating hours that produce savings from a floating head pressure control system will correlate with outside air temperature. When temperatures are below the condensing setpoint, the controls will operate. For a set point of 70ºF , the operating hours are 7713.[1]

Load Shapes

70b Floating Head Pressure Control

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
70	Floating Head Pressure Control	Active	33.3 %	37.1 %	12.9 %	16.8 %	100.0 %	0.0 %

Net Savings Factors

Measures

RFRFHCON	Refrigeration floating head pressure controls

Tracks [Base Track]

6012CNIR [is base track]	C&I Retro
6013CUST [is base track]	Cust Equip Rpl

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
C&I Retro	6012CNIR	RFRFHCON	0.94	1.00
Cust Equip Rpl	6013CUST	RFRFHCON	0.94	1.00

Persistence

The persistence factor is assumed to be one.

Lifetimes

15 years.[5]

Measure Cost

Floating Head Pressure Control Costs per Horsepower ($/HP)[6]

Unit Type	Temperature Range		
	Low Temperature (Freezer)	Medium Temperature (Refrigerator)	Unknown Temperature[3]
Self-Contained Unit (SCU)	$296	$390	$360
Remote Condensing Unit (RCU)	$157	$207	$191

Unknown Type[4]	$227	$299	$275

Water Descriptions

There are no water algorithms or default values for this measure.

Reference Tables

Footnotes

[1] Annual average of hours for Vermont that temperature is below 70ºF. This is the condensing temperature that is set for the floating head pressure control as required by EVT. Hours are deemed from TMY3 weather data for Vermont. See "FHP Savings Extrapolation.xlsx" for further details.

[2] Derived from RTF saving estimates for the NW climate zone and extrapolated to Vermont climate zone by using cooling degree-days. RTF, "Commercial: Grocery - Floating Head Pressure Controls for Single Compressor Systems", workbook *ComGroceryFHPCSingleCompressor_v1_5.xlsm*, 2016.

[3] Unknown values based on weighted average; 2010 ASHRAE Refrigeration Handbook, page 15.1 "Medium- and low-temperature display refrigerator line-ups account for roughly 68% and 32%, respectively, of a typical supermarket's total display refrigerators."

[4] For unit type unknown, it is assumed 50/50 split of self-contained and remote condensing units.

[5] California DEER 2014 Effective Useful Life (EUL) table. See Reference file "DEER2014 EUL Table Update.xlsx".

[6] Costs are based on number of additional valves per condenser motor for different HP ratings and includes installation labor costs. Costs are averaged and shown on a per HP basis. See reference file RTF, "Commercial: Grocery - Floating Head Pressure Controls for Single Compressor Systems", workbook *ComGroceryFHPCSingleCompressor_v1_5.xlsm*, 2016.

High Efficiency Condensing Units

Measure Number: I-E-14 a
Portfolio: EVT TRM Portfolio 2017-09
Status: Active
Effective Date: 2018/1/1
End Date: [None]
Program: Business Energy Services
End Use: Refrigeration

Update Summary

This is a new measure characterization.

Referenced Documents

Refrigeration Analysis Tool v5d_Modified for HECU TRM :contains the template of the analysis tool used to establish savings for this measure

Trenton Data & Heatcraft Data: product data sheets from which capacities were derived for analysis

HECU Capacity Inputs and Savings Outputs F: outlines the methodology to determine average capacities from product data and summarizes the analysis outputs from the analysis tool

HECU Connected kW Load Savings: shows the derivation of connect load savings for this measure

HECU Compressor Fan Loadshape F: shows the derivation of the custom loadshape developed for HECU compressor fan energy and demand savings

HECU Incremental Costs: outlines the methodology used to establish incremental costs

- HECU Incremental Costs
- Trenton Data
- Heatcraft Data
- Refrigeration Analysis Tool v5d_Modified for HECU TRM
- HECU Capacity Inputs and Savings Outputs F
- HECU Compressor Fan Loadshape F
- HECU Connected kW Load Savings

Description

This characterization captures the savings attributed to an upstream commercial refrigeration condensing unit initiative capitalizing on market opportunities to drive the installation of efficient condensing units instead of standard baseline units. Applicable to condensing units serving Low (0°F) and Medium (32°F) conditioned environments, an efficient condensing unit is defined by units incorporating three requisite attributes: an efficient scroll compressor, floating head pressure controls, and modulating compressor fan speed capabilities (for analysis purposes low/high speed capbilities are assumed, however some units are equipped with variable speed drives that would realize additional savings). The collective effect of these three features results in the refrigeration load requirements being met while using less power as compared to a baseline unit. Units with compressor horsepower ratings in the range of 1-5hp are eligible to participate in the upstream initiative. Eligibility is limited to outdoor units. Savings claimed assume the efficient unit replaces a baseline outdoor unit, however it's worth noting that a customer replacing an indoor unit with an outdoor unit would likely realize additional savings.

As illustrated in the following sections, prescriptive deemed savings will be claimed based on a unit's temperature application, power phase requirements and compressor horsepower rating. Of note is that for the purposes of the TRM, horsepower ratings are specific in 1/2 horsepower increments. It it believed that most eligible units will map neatly to an established horsepower category, however in the event a qualifying unit falls somewhere in the middle of an established category, it will be assigned to the closest category with the most conservative total kWh savings.

Baseline Efficiencies

A baseline condensing unit is one with a standard compressor efficiency rating (as defined and established by EVT's Refrigeration Analysis Tool), no floating head pressure controls, and single speed compressor fan motors.

Efficient Equipment

High Efficiency Condensing Units must have scroll compressor technology, incorporate floating head pressure controls, and have the ability to modulate compressor fan speed.

Algorithms

Electric Demand Savings

A full derivation of demand savings is shown in reference file "HECU Connected kW Load Savings." The tabulated energy saving values for each of the three components (scroll compressor, compressor fans, floating head pressure contols) was divided by their respective annual full load operating hours, as described in the following table:

Component	Annual Full Load Operating Hours	Source
Scroll Compressor	2913.35171232877 (w/Economizer), 3910 (w/o Economizer)	EVT Refrigeration Analysis Tool (CATInput worksheet)
Compressor Fan(s)	6087	As derived in HECU Compressor Fan Loadshape F
Floating Head Pressure Controls	7221	EVT Refrigeration Analysis Tool (CATInput worksheet)

The resulting connected load savings is shown in the following table. Units are in kW. For the pruposes of screening and coincident peak demand savings claims, the savings for each component will be treated separately against its respective loadshape, as described in the Load Shapes section below.

Temp	Phase	HP	Scroll Compressor	Condenser Fan(s)	Floating Head Pressure Controls	Total
Medium	1	1	0.21997	0.07605	0.12982	0.42585
		1.5	0.16477	0.08149	0.15421	0.40047
		2	0.19216	0.09504	0.17984	0.46704
		2.5	0.22508	0.11132	0.21065	0.54705
		3	0.21755	0.14153	0.28241	0.64149
		3.5	0.30964	0.16165	0.30956	0.78086
		4	0.34246	0.17879	0.34237	0.86362
		4.5	0.34856	0.18197	0.34847	0.87901
		5	0.25508	0.18916	0.38505	0.82928
	3	1	0.15623	0.06806	0.11695	0.34125
		1.5	0.13245	0.07799	0.14330	0.35374
		2	0.15447	0.09095	0.16712	0.41255
		2.5	0.18093	0.10654	0.19576	0.48323
		3	0.18620	0.13028	0.24637	0.56284
		3.5	0.27717	0.14907	0.26912	0.69535
		4	0.30654	0.16487	0.29764	0.76905
		4.5	0.31200	0.16780	0.30294	0.78275
		5	0.27084	0.18512	0.34883	0.80478
Low	1	2	0.12604	0.09116	0.16728	0.38449
		2.5	0.11317	0.10645	0.20257	0.42219
		3	0.12627	0.11877	0.22601	0.47105
		3.5	0.15284	0.14376	0.27357	0.57016
		4.5	0.15564	0.15828	0.30390	0.61783
	3	2	0.09065	0.08296	0.15547	0.32908
		2.5	0.09374	0.09918	0.18896	0.38187
		3	0.10458	0.11065	0.21082	0.42606
		3.5	0.12659	0.13394	0.25518	0.51571
		4.5	0.16792	0.15403	0.28875	0.61070

Electric Energy Savings

As described in full detail in the reference file "Refrigeration Analysis Tool v5d_Modified for HECU TRM" savings for High Efficiency Condensing Units were established by running iterations in EVT's Refrigeration Analysis Tool, with considerations for differences in refrigeration temperature environment, capacity, single or three-phase power requirements, and the existence of an economizer. For the pruposes of screening and, the savings for each componend will be treated separately against its respective loadshape, as described in the Load Shapes section below. The following table outlines the energy savings (kWh) associated with each specified unit:

Temp	Phase	HP	Scroll Compressor	Condenser Fan(s)	Floating Head Pressure Controls	Total
Medium	1	1	838.1	462.9	937.5	2238.5
		1.5	627.8	496.0	1113.5	2237.4
		2	732.2	578.5	1298.6	2609.3
		2.5	857.6	677.6	1521.1	3056.3
		3	828.9	861.5	2039.3	3729.7
		3.5	1179.8	984.0	2235.4	4399.1
		4	1304.9	1088.3	2472.3	4865.4
		4.5	1328.1	1107.7	2516.3	4952.1
		5	971.9	1151.4	2780.5	4903.8
	3	1	595.3	414.3	844.5	1854.1
		1.5	504.7	474.7	1034.8	2014.2
		2	588.6	553.6	1206.8	2349.0
		2.5	689.4	648.5	1413.6	2751.4
		3	709.4	793.0	1779.0	3281.5
		3.5	1056.0	907.4	1943.3	3906.7
		4	1168.0	1003.5	2149.3	4320.8
		4.5	1188.8	1021.4	2187.6	4397.8
		5	1032.0	1126.8	2518.9	4677.6
Low	1	2	521.7	554.9	1208.0	2284.5
		2.5	468.4	648.0	1462.8	2579.2
		3	522.6	722.9	1632.0	2877.6
		3.5	632.6	875.1	1975.4	3483.1
		4.5	644.2	963.5	2194.5	3802.2

	3	2	375.2	505.0	1122.7	2002.8
		2.5	388.0	603.7	1364.5	2356.1
		3	432.9	673.5	1522.3	2628.7
		3.5	523.9	815.3	1842.7	3181.9
		4.5	695.0	937.6	2085.1	3717.7

Fossil Fuel Savings

Not applicable.

Load Shapes

Loadshape 14a will be used to capture the coincident peak energy and demand savings attributed to the energy savings associated with the scroll compressor.

Loadshape 70a will be used to capture the coincident peak energy and demand savings attributed to the energy savings associated with floating head pressure controls.

The custom loadshape described below will be used to capture the coincident peak energy and demand savings attributed to low speed compressor fan operation. A full derivation of this loadshape is available in the reference file "HECU Compressor Fan Loadshape F".

Energy				Demand		FLH
Winter Peak	Winter Off-Peak	Summer Peak	Summer Off-Peak	Winter	Summer	
Oct-May, 7am-11pm, M-F	Oct-May, Weekends all day and 11pm-7am, M-F	Jun-Sept, 7am-11pm, M-F	Jun-Sept, Weekends all day and 11pm-7am, M-F	Dec-Jan, 5pm-7pm, M-F, non-holiday	Jun-Aug, 1pm-5pm, M-F, non-holiday	
40.09%	47.99%	4.09%	7.84%	100.00%	1.15%	6087.00

14a Commercial Refrigeration
70b Floating Head Pressure Control

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
14	Commercial Refrigeration	Active	33.0 %	32.6 %	17.0 %	17.4 %	69.0 %	77.2 %
70	Floating Head Pressure Control	Active	33.3 %	37.1 %	12.9 %	16.8 %	100.0 %	0.0 %

Net Savings Factors

Measures

RFROHECU	Outdoor High Efficiency Condensing Unit

Tracks [Base Track]

6013UPST [is base track]	Upstream - Commercial

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Upstream - Commercial	6013UPST	RFROHECU	1.00	1.00

Lifetimes

The expected measure life is 13 years, consistent with EVT's custom refrigeration analysis assumptions for a scroll compressor.

Measure Cost

Incremental costs are established based on compressor horsepower rating, as indicated in the following table[1]:

Horsepower	Incremental Cost
1.0	$200.50
1.5	$348.90
2.0	$600.00
2.5	$586.50
3.0	$573.00
3.5	$899.00
4.0	$1225.00
4.5	$1298.50
5.0	$1372.00

Footnotes

[1] On August 21, 2017 several Efficiency Vermont staff members met with FW Webb representatives in Rutland, VT. Representing FW Webb were 2

General Managers (Darrell Read and Brian Bradley) as well as the Director of Refrigeration (Rich Boynton) and Business Development Manager (Chuck Fiorino). During this meeting, cost information comparing standard (non-controlled, hermetic compressor) condensers and premium efficiency condensers (floating head pressure controls and scroll compressors) was shared for compressors rated at 2,3,4 and 5 horsepower. The costs for other capacities were extrapolated per the methods outlined in the referenced document "HECU Incremental Costs.xlsx".

Refrigerated Case Covers

Measure Number: I-E-2 c
Portfolio: 93
Status: Active
Effective Date: 2017/1/1
End Date: [None]
Program: Business Energy Services
End Use: Refrigeration

Update Summary

- Measure updated to utilize the U.S. Department of Energy, Energy Conservation Standards for Commercial Refrigeration Equipment Engineering Spreadsheet
- Measure updated to utilize more recent Measure Cost and case cover efficiencies

Referenced Documents

- Northwest Regional Technical Forum, Commercial Grocery Strip Curtain analysis, 2016. "ComGroceryStrip_v1_6.xlsm".
- PG&E, "Night Covers for Open Vertical and Horizontal Display Cases (Low and Medium Temperature Cases)", Work Paper PGECOREF101, July 2014.
- PG&E, "Strip Curtains for Doorways to Refrigerated Storage", Work Paper PGECOREF103, May 2012.
- EVT Refrigeration Analysis Tool v5b
- Refrigerated Case Covers Study 2016 v2.xlsx

Description

By covering refrigerated cases, the heat gain due to the spilling of refrigerated air and convective mixing with room air is reduced at the case opening. Strip curtains can be deployed continuously and allow the customer to reach through the curtain to select the product. Continuous curtains can be pulled down overnight while the store is closed. Strip curtains are not used for low temperature, multi-deck applications. Glass door retrofits are a better choice for these applications.

Algorithms

Electric Demand Savings

ΔkW	= (HG × EF × CL × DF) / (EER × 1000)

Symbol Table

Electric Energy Savings

ΔkWh	= ΔkW × Usage × 365

Symbol Table

Fossil Fuel Savings

Where:

ΔkW	=	Gross customer connected load kW savings for the measure (kW)
ΔkWh	=	Gross customer annual kWh savings for the measure (kWh)
1000	=	Conversion from watts to kW (W/kW)
365	=	Days / Year
CL	=	Refrigerated case length in feet (ft). Case length is the open length of the refrigerated box. If the unit is two sided use the open length of both sides.
DF	=	Disabling Factor to account for the portion of the time that the strip curtain is intentionally disabled, as well as time to access the product. The Disabling factor is assumed to be 80% for strip curtains and 100% for continuous case covers.[1]
EER	=	Compressor efficiency (Btu/hr-watt). The average compressor efficiency (EER) is 11.36 for medium temperature applications (case temperature 10°F to 40°F) and 17.7 for high temperature applications (case temperature 45°F to 65°F).[2]
EF	=	Efficiency Factor: Fraction of heat gain prevented by case cover. The Efficiency Factor for strip curtains is 0.82.[3] The Efficiency Factor for continuous covers is 0.50.[4]

HG = Loss of cold air or heat gain for refrigerated cases with no cover (Btu/hr-ft opening). The heat gain is 734 for open cooler applications.[5]

Usage = Average hours per day that case cover is in place (hrs/day). Assume 24 hrs/day for strip curtains. Assume 8 hours per day for continuous covers.

Baseline Efficiencies

The baseline condition is a refrigerated case without a cover.

Efficient Equipment

High efficiency is a refrigerated case with a strip curtain or night cover.

Load Shapes

Source: Strip curtain uses the same energy distribution as the previously-developed commercial refrigeration loadshape in Vermont State Cost-Effectiveness Screening Tool. Coincident factors for strip curtains are set at 100% since the calculated kW savings is an average for every hour. The night case covers loadshape is based on the savings occurring from 11 PM to 7 AM.

67a Strip Curtain
77a Refrigeration Night Covers

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
67	Strip Curtain	Active	33.0 %	32.6 %	17.0 %	17.4 %	100.0 %	100.0 %
77	Refrigeration Night Covers	Active	6.0 %	60.6 %	3.0 %	30.4 %	0.0 %	0.0 %

Net Savings Factors

Measures

RFRCOVER	Refrigerator covers

Tracks [Base Track]

6013PRES [is base track]	Pres Equip Rpl
6014PRES [is base track]	6014PRES

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Pres Equip Rpl	6013PRES	RFRCOVER	0.95	1.00
6014PRES	6014PRES	RFRCOVER	0.95	1.05

Persistence

The persistence factor is assumed to be one.

Lifetimes

Strip curtains: 4 years

Continuous covers: 5 years

Measure Cost

Typically costs are approximately $42/ft for continuous curtains[4] and $40/ft for strip curtains.[6]

O&M Cost Adjustments

Strip curtains require regular cleaning -- $4.33/yr-ft (1 minute/foot every two weeks at $10/hr).

Continuous curtains require that they are pulled down nightly – $2.53/yr-ft (5 sec. per 4-foot section, twice per day, at $10/hr)[7]

Fossil Fuel Descriptions

There are no fossil fuel algorithms or default values for this measure.

Water Descriptions

There are no water algorithms or default values for this measure.

Reference Tables

Demand and Energy Savings for
Strip and Continuous Refrigeration Covers[8]

	Refrigerated Space Temperature			
Cover Type	**Medium Temp (10°F to 40°F)**		**High Temp (45°F to 65°F)**	
	Demand Savings (ΔkW/ft)	**Annual Energy Savings (ΔkWh/ft)**	**Demand Savings (ΔkW/ft)**	**Annual Energy Savings (ΔkWh/ft)**
Strip Curtains	0.041	363	0.027	238
Continuous (Night Cover)	0.032	92	0.021	61

Footnotes

[1] TAG agreement established January 2006. Reviewed June 2016.

[2] Average EER values were calculated as the average of standard reciprocating and discus compressor efficiencies, using a typical condensing temperature of 90°F and saturated suction temperatures (SST) of 20°F for medium temperature applications and 45°F for high temperature applications. EER is developed in EVT "Refrigeration Analysis Tool v5b", as seen on the 'Overall EERs' sumamry tab. Values are developed using data from Emerson Climate Technology software. Last updated November 2013.

[3] Calculated from the average effectiveness against infiltration or reduction of heat infiltration pre and post strip curtain installation. Derived in Northwest Regional Technical Forum, Commercial Grocery Strip Curtain analysis, 2016. See reference file "ComGroceryStrip_v1_6.xlsm". Values on tab "Cooling Load Calc".

[4] PG&E, "Night Covers for Open Vertical and Horizontal Display Cases (Low and Medium Temperature Cases)", Work Paper PGECOREF101, July 2014. Page 7, Section 4.3.

[5] Calculated from the average baseline (no cover) infiltration of commercial coolers. Derived in Northwest Regional Technical Forum, Commercial Grocery Strip Curtain analysis, 2016. See reference file "ComGroceryStrip_v1_6.xlsm". Value on tab "Cooling Load Calc".

[6] Cost per linear foot derived with the assumption that a typical display case merchandise cooler has an internal height of 4 feet and costs per square foot is $10 as listed in the following reference. PG&E, "Strip Curtains for Doorways to Refrigerated Storage", Work Paper PGECOREF103, May 2012. Page 31, Section 4.3.

[7] Labor rate of $10/hour is effective in the state of Vermont as of January 1, 2017. Rate is based on Vermont Department of Labor, "Establishment of Minimum Wage", Section 384, Chapter 5, Title 21, Subsection (a).

[8] For detailed calculation of demand and energy savings see reference file "Refrigerated Case Covers Study 2016 v2.xlsx"

Commercial Reach-In Refrigerators and Freezers

Measure Number:	I-E-3 e
Portfolio:	EVT TRM Portfolio 2018-01
Status:	Active
Effective Date:	2018/1/1
End Date:	[None]
Program:	Business Energy Services
End Use:	Refrigeration

Update Summary

- Measure updated to utilize new Energy Star V4.0 requirements for efficient equipment (Effective March 2017)
- Measure updated to utilize new Federal Standard of efficiency (baseline) for refrigeration equipment (Effective March 2017)
- New costs associated with Energy Star Version 4.0

Referenced Documents

- Unit Energy Savings (UES) Measures and Supporting Documentation, ComRefrigeratorFreezer_v3_2.xlsm
- 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Effective/Remaining Useful Life Values"
- CA_CEUS_COMM_DATA.xlsx
- Itron Inc., "California Commercial End-Use Survey", prepared for California Energy Commission, March 2006.
- evt-reach-in-fridge-and-freezer-energy-star-version-4-0-analysis-december-2017

Description

The measure described here is a high-efficiency packaged commercial reach-in cooler (refrigerator or freezer) with solid or glass doors, typically used by foodservice establishments. This includes one, two and three door reach-in, roll-in/through and pass-through commercial coolers. Beverage merchandisers – a special type of reach-in refrigerator with glass doors – are not included in this characterization.

Algorithms

Electric Demand Savings

ΔkW	= ΔkWh / Hours

Symbol Table

Electric Energy Savings

ΔkWh	= value from savings table in Reference Tables section of this measure(varies by capacity of refrigeration unit).

Symbol Table

Fossil Fuel Savings

Where:

ΔkW	=	Gross customer connected load kW savings for the measure (kW)
ΔkWh	=	Gross customer annual kWh savings for the measure (kWh)
Hours	=	Annual operating hours (8760 hours)[1]

Baseline Efficiencies

The baseline equipment is assumed to be a refrigerator or freezer meeting the minimum federal manufacturing standards as specified by Federal Standards effective March 2017.[2] See the average baseline energy use in the savings table in the Reference Tables section.

Efficient Equipment

A high efficiency reach-in refrigerator or freezer is one that meets the requirements of the ENERGY STAR 4.0 specifications (those meeting the ENERGY STAR specifications as of March 2017). Refer to the Reference Tables section for the detailed specifications.

Operating Hours

Load Shapes

Commercial Reach-In Refrigerator & Freezer load shape is developed using the California Commercial End-Use Survey.[3]

119a Commercial Reach-In Refrigerator & Freezer

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
119	Commercial Reach-In Refrigerator & Freezer	Active	31.9 %	32.3 %	17.7 %	18.0 %	97.9 %	118.6 %

Net Savings Factors

Measures

RFRCOMRF	Commercial refrigerator
RFRCOMFZ	Commercial freezer

Tracks [Base Track]

6013PRES [is base track]	Pres Equip Rpl
6014PRES [is base track]	6014PRES

Persistence

The persistence factor is assumed to be one.

Lifetimes

12 years.[4]

Measure Cost

Based on examination of list prices and price studies performed by others, the determined incremental costs are tabulated below.

Incremental Cost for Refrigerators and Freezer[5]

Description and Volume	Refrigerator	Freezer
(cu. ft.)	Incremental Unit Cost Relative to Baseline	
Solid Door		
0 ≤ V < 15	$ 217	$ 275
15 ≤ V < 30	$ 483	$ 569
30 ≤ V < 50	$ 1,037	$ 1,309
50 ≤ V	$ 1,571	$ 1,939
Glass Door		
0 ≤ V < 15	$ 172	$ 280
15 ≤ V < 30	$ 502	$ 776
30 ≤ V < 50	$ 1,076	$ 1,415
50 ≤ V	$ 1,643	$ 2,175
Chest		
Solid/Glass	$ 452	$ 1,354

Note: V = internal volume in cubic feet

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O&M Cost Adjustments

No differences in O&M costs are apparent between the standard and efficient refrigerators.

Reference Tables

Savings for Refrigerators and Freezers[6]

Description and Volume	Refrigerator (kWh/year)		Freezer (kWh/year)	
(cu. ft.)		Annual kWh Savings		Annual kWh Savings

	Annual Energy Use of Average Baseline	Relative to Base Case	Annual Energy Use of Average Baseline	Relative to Base Case
		ENERGY STAR 4.0		ENERGY STAR 4.0
Solid Door				
0 ≤ V < 15	660	234	1229	208
15 ≤ V < 30	861	267	2007	366
30 ≤ V < 50	1278	255	3961	469
50 ≤ V	1681	422	5624	695
Glass Door				
0 ≤ V < 15	567	164	1974	395
15 ≤ V < 30	1054	275	3566	713
30 ≤ V < 50	1900	570	5613	1123
50 ≤ V	2735	598	8051	1610
Chest				
Solid	476	230	800	228
Glass	308	62	970	398

Specifications for Refrigerators and Freezers[7][8]

Description and Volume (cu. ft.)	**MDECs (Maximum Daily Energy Consumption, kWh/day)**			
	Refrigerator		**Freezer**	
	Baseline	ENERGY STAR 4.0	Baseline	ENERGY STAR 4.0
Solid Door				
0 ≤ V < 15	0.05V+1.36	0.022V+0.97	0.22V+1.38	0.21V+0.90
15 ≤ V < 30		0.066V+0.31		0.12V+2.248
30 ≤ V < 50		0.04V+1.09		0.285V-2.703
50 ≤ V		0.024V+1.89		0.142V+4.445
Glass Door				
0 ≤ V < 15	0.1V+0.86	0.095V+0.445	0.29V+2.95	0.232V+2.36
15 ≤ V < 30		0.05V+1.12		
30 ≤ V < 50		0.076V+0.34		
50 ≤ V		0.105V-1.111		
Chest				
Solid	0.05V+0.91	0.05V+0.28	0.06V + 1.12	0.057V+0.55
Glass	0.06V+0.37		0.08V+1.23	

Note: V = internal volume in cubic feet.

Footnotes

[1] The refrigerator is assumed to always be plugged in and operating 8760 hours per year. This provides an annual average kW demand savings.

[2] United States Department of Energy, 10 CFR Part 431, *"Energy Conservation Standards for Commercial Refrigeration Equipment"*, Document last updated August 25, 2017. March 27, 2017 is the manufacturer applicability date to comply with these standards.

[3] Loadshape derived from data in the California Commercial End-Use Survey. Itron Inc., "California Commercial End-Use Survey", prepared for California Energy Commission, March 2006. See reference file "CA_CEUS_COMM_DATA.xlsx". The California Commercial End-Use Survey (CEUS) is a comprehensive study of commercial building sector end-use energy use. Itron performed the survey under contract to the California Energy Commission (CEC), and with the support of Pacific Gas & Electric, San Diego Gas and Electric, Southern California Edison, Southern California Gas Company and the Sacramento Municipal Utility District. A stratified, random sample of 2,800 commercial facilities was targeted and a sample of 2,790 were actually completed. Commercial premises are weighted and aggregated to building segment results.

[4] 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Effective/Remaining Useful Life Values", California Public Utilities Commission, December 16, 2008. See reference file "Effective Useful Life EUL_Summary_10-1-08.xls".

[5] Northwest Regional Technical Forum, ENERY STAR Version 4.0 Analysis. Refer to CostData&Analysis tab in ComRefrigeratorFreezer_v4_2.xlsm. These costs include the average cubic foot size from this analysis and applies to the Northwest RTF's average cost per cubic foot.

[6] Calculated savings from baseline. See reference: EVT_Reach_In_Fridge_and_Freezer_2017-ENERGY STAR Version 4.0_Analysis_December_2017.xlsx.

[7] United States Department of Energy, 10 CFR Part 431, *"Energy Conservation Standards for Commercial Refrigeration Equipment",* March, 2017.

[8] ENERGY STAR, *"ENERGY STAR Program Requirements for Commercial Refrigerators and Freezers"*, v4.0, Effective January 1, 2017.

ENERGY STAR Commercial Ice Makers

Measure Number: I-E-5 d
Portfolio: EVT TRM Portfolio 2017-08
Status: Inactive
Effective Date: 2018/1/1
End Date: 2018/12/31
Program: Business Energy Services
End Use: Refrigeration

Update Summary

This update reflects new incremental costs and that a majority of ice makers on the market meet ENERGY STAR water efficiency standards, so therefore water savings have been moved from this characterization. This update also aligns with the new ENERGY STAR Version 2.0 criteria.

Referenced Documents

- Nadel 2002 Packaged Commercial Refrigeration
- "A Field Study to Characterize Water and Energy Use of Commercial Ice-Cube Machines and Quantify
- 3. Ice Machine Field Study: Energy and Water Savings with Ice Machine Upgrade and Load Shifting
- 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Effective/Remaining Use
- ENERGY STAR calculator (commercial_kitchen_equipment_calculator.xls), http://www.energystar.gov/i
- Food Service Electic Measure Workpapers 11-08-05
- comm-ice-maker-trm-update-calculations-August 2017

Description

This measure relates to the installation of a new ENERGY STAR qualified commercial ice machine. The ENERGY STAR label applied to air-cooled, cube-type machines including ice-making head, self-contained, and remote-condensing units. This measure excludes flake and nugget type ice machines. This measure could relate to the replacing of an existing unit at the end of its useful life, or the installation of a new system in a new or existing building.

This measure was developed to be applicable to the following program types: TOS and NC. If applied to other program types, the measure savings should be verified.

Estimated Measure Impacts

Algorithms

Electric Demand Savings

$\Delta kW = \Delta kWh / (HOURS \times DC)$

Symbol Table

Electric Energy Savings

$\Delta kWh = ((kWh_{base} - kWh_{ee})/ 100) \times (DC \times H) \times 365$

Where:

ΔkW = gross customer connected load kW savings for the measure (kW)

ΔkWh = gross customer annual kWh savings for the measure (kWh)

100 = conversion factor to convert kWhbase and kWhee into maximum kWh consumption per pound of ice.

365 = Days per year

DC = Duty Cycle of the ice machine[1]
0.57

H = Harvest Rate (pounds of ice made per day)
assumed harvest rates reference table #2 below

HOURS = annual operating hours[2]
8760

kWh_{base} = maximum kWh consumption per 100 pounds of ice for the baseline equipment
calculated as shown in reference table #1 below using the actual Harvest Rate (H) of the efficient equipment.

kWh_{ee} = maximum kWh consumption per 100 pounds of ice for the efficient equipment calculated as shown in reference table #1 below using the actual Harvest Rate (H) of the efficient equipment.

Baseline Efficiencies

In order for this characterization to apply, the baseline equipment is assumed to be a commercial ice machine meeting federal equipment standards established January 1, 2010.

High Efficiency

In order for this characterization to apply, the efficient equipment is assumed to be a new commercial ice machine meeting the minimum ENERGY STAR efficiency level standards.

Operating Hours

Unit is assumed to be connected to power 24 hours per day, 365 days a year.

Load Shapes

14a Commercial Refrigeration

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
14	Commercial Refrigeration	Active	33.0 %	32.6 %	17.0 %	17.4 %	69.0 %	77.2 %

Net Savings Factors

Measures

RFRCOMIM	Commercial icemaker

Tracks [Base Track]

6012CNIR [is base track]	C&I Retro
6013CUST [is base track]	Cust Equip Rpl
6013PRES [is base track]	Pres Equip Rpl

Persistence

The persistence factor is assumed to be one.

Lifetimes

10 years[3]

Measure Cost

The incremental capital cost for this measure is provided below[4].

Harvest Rate (H)	Incremental Cost
100-200 lb ice machine	$296
201-300 lb ice machine	$312
301-400 lb ice machine	$559
401-500 lb ice machine	$981
501-1000 lb ice machine	$1,485
1001-1500 lb ice machine	$1,821
>1500 lb ice machine	$2,194

O&M Cost Adjustments

No differences in O&M costs are apparent between the standard and efficient ice-makers.

Fossil Fuel Description

There are no fossil fuel algorithms or default values for this measure.

Incentive Level

Water Descriptions

While the ENERGY STAR labeling criteria require that certified commercial ice machines meet certain "maximum potable water use per 100 pounds of ice made" requirements, such requirements are intended to prevent equipment manufacturers from gaining energy efficiency at the cost of water consumptions. A review of the AHRI Certification Directory[5] indicates that approximately 81% of air-cooled, cube-type machines meet the ENERGY STAR potable water use requirement. Therefore, there are no assumed water impacts for this measure.

Reference Tables

Reference Table #1

Energy Savings Algorithms[6]

Ice Machine Type Air Cooled, batch or continuous	Baseline kWh per 100 gallons of ice	Efficient kWh per 100 gallons of ice
Ice Making Head (H < 450)	10.26 – 0.0086×H	9.23 – 0.0077×H
Ice Making Head (H ≥ 450)	6.89 – 0.0011×H	6.20 – 0.0010×H
Remote Condensing Unit (H < 1000)	8.85 – 0.0038×H	8.05 – 0.0035×H
Remote Condensing Unit (H ≥ 1000)	5.1	4.64
Self Contained Unit (H < 175)	18 – 0.0469×H	16.7 – 0.0436×H
Self Contained Unit (H ≥ 175)	9.8	9.11

Reference Table #2

Annual Energy Consumption/Savings per Ice Machine [7]

Ice Machine Type Air Cooled, batch or continuous	Assumed Ice harvest rate (H) (lbs. ice/day)	ΔkWh	ΔkW
Ice Making Head (H < 450)	331	505	0.101
Ice Making Head (H ≥ 450)	814	1031	0.206
Remote Condensing Unit (H < 1000)	770	912	0.183
Remote Condensing Unit (H ≥ 1000)	1,449	1,388	0.278
Self Contained Unit (H < 175)	96	196	0.039
Self Contained Unit (H ≥ 175)	271	389	0.078

Footnotes

[1] Duty cycle varies considerably from one installation to the next. TRM assumptions from Vermont, Wisconsin, and New York vary from 40 to 57%, whereas the ENERGY STAR Commercial Ice Machine Savings Calculator < http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/Calc_Ice_Machines.xls> assumes a value of 75%. A field study of eight ice machines in California indicated an average duty cycle of 57% ("A Field Study to Characterize Water and Energy Use of Commercial Ice-Cube Machines and Quantify Saving Potential", Food Service Technology Center, December 2007). Furthermore, a report prepared by ACEEE assumed a value of 40% (Nadel, S., Packaged Commercial Refrigeration Equipment: A Briefing Report for Program Planners and Implementers, ACEEE, December 2002). The value of 57% was utilized since it appears to represent a high quality data source.

[2] Unit is assumed to be connected to power 24 hours per day, 365 days per year.

[3] 2008 Database for Energy-Efficiency Resources (DEER), Version 2008.2.05, "Effective/Remaining Useful Life Values," California Public Utilities Commission, December 16, 2008.

[4] These values are from electronic work papers prepared in support of San Diego Gas & Electric's "Application for Approval of Electric and Gas Energy Efficiency Programs and Budgets for Years 2009-2011", SDGE, March 2, 2009. Accessed on 4/17/17 .

[5] 1AHRI Certification Directory, Accessed on 7/7/10.

[6] ENERGY STAR calculator (commercial_kitchen_equipment_calculator.xls), http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/commercial_kitchen_equipment_calculator.xlsx as of October 28, 2013.

[7] Refer to analysis document: Comm Ice Maker TRM Update Calculations_FINAL.xlsx. Average assumed ice harvest rate based on average of bins in ENERGY STAR commercial kitchen equipment calculator.

Evaporator Fan Motor Controls

Measure Number:	I-E-7 d
Portfolio:	EVT TRM Portfolio 2017-05
Status:	Active
Effective Date:	2017/7/1
End Date:	[None]
Program:	Business Energy Services
End Use:	Refrigeration

Update Summary

- Measure updated to include Synchronous fan motors and reports the same costs but on an average per fan basis.

Referenced Documents

- The Cadmus Group, Commercial Refrigeration Loadshape Project Final Report, Northeast Energy Efficiency Partnerships, Regional Evaluation, Measurement, and Verification Forum, Lexington, MA 2015.
- Oak Ridge National Laboratory, "Q-Sync Motors in Commercial Refrigeration: Preliminary Test Results and Projected benefits", 2015.
- Evaporator Fan Controls_NEEP_ICS4 Final June 23 2015.xlsx
- 2016 Vermont Business Sector Market Characterization and Assessment Study
- Evaporator Fan Motor Control 2017 Update v2

Description

Walk-in cooler evaporator fans typically run all the time; 24 hrs/day, 365 days/yr. The continuous operation is due to the need to provide cooling when the compressor is running, and to provide air circulation when the compressor is not running. Evaporator fans controls can be added to reduce fan run time or speed depending on the call for cooling and air circulation, while maintaing circulation requirements.

Algorithms

Electric Demand Savings

$$\Delta kW = kW_{Fan} \times n_{Fans} \times LRF \times BF$$

Symbol Table

Electric Energy Savings

$$\Delta kWh = \Delta kW \times 8760$$

Symbol Table

Fossil Fuel Savings

Where:

ΔkW	=	Gross customer connected load kW savings for the measure (kW)
ΔkWh	=	Gross customer annual kWh savings for the measure (kWh)
8760	=	Hours / Year
BF	=	Bonus factor for reduced cooling load from eliminating heat generated by the evaporator fan inside the cooler or freezer (1.4 for coolers, 1.8 for freezers)[1]
kW_{Fan}	=	Connected load kW of each evaporator fan (0.139 kW for SP, 0.051 kW for ECM, 0.046 kW for Synchronous)[2] If motor type is unknown, default value is 0.097 kW.[3]
LRF	=	Load Reduction Factor for motor controlled units (31.3%)[4]
n_{Fans}	=	Number of evaporator fans driven by the controls

Baseline Efficiencies

The baseline condition is a refrigeration system without an evaporator fan control.

Efficient Equipment

High efficiency is a refrigeration system with an evaporator fan control and a smaller wattage circulating fan.

Load Shapes

For Loadshape details, see reference: Evaporator Fan Motor Control Study 2016 v2.xlsx

68b Evaporator Fan Control

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
68	Evaporator Fan Control	Active	27.0 %	40.0 %	14.0 %	19.0 %	83.1 %	83.1 %

Net Savings Factors

Measures

RFRFMCON	Refrigeration fan motor controls

Tracks [Base Track]

6014PRES [is base track]	6014PRES

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
6014PRES	6014PRES	RFRFMCON	0.95	1.05

Lifetimes

15 years

Measure Cost

The cost for an evaporator fan motor controller including labor is $91 per fan.[5]

O&M Cost Adjustments

There are no standard operation and maintenance cost adjustments used for this measure.

Fossil Fuel Descriptions

There are no fossil fuel algorithms or default values for this measure.

Water Descriptions

There are no water algorithms or default values for this measure.

Reference Tables

Savings for Evaporator Fan Motor Controls[6]

Energy Savings for Evaporator Fan Motor Controls				
Temperature Range	Savings by Motor Type (ΔkWh)			
	SP	ECM	Synchronous	Unknown
Low (<25F)	687	249	225	479
Medium / High (25-40F / 41-65F)	534	194	175	373

Savings is on a per fan basis, not per controller. A single control unit can control several fans.

Demand Savings for Evaporator Fan Motor Controls				
Temperature Range	Savings by Motor Type (ΔkW)			
	SP	ECM	Synchronous	Unknown
Low (<25F)	0.078	0.028	0.026	0.055
Medium / High (25-40F / 41-65F)	0.061	0.022	0.020	0.043

Savings is on a per fan basis, not per controller. A single control unit can control several fans.

Footnotes

[1] Bonus factors as derived in the NEEP Refrigeration Loadshape Report. The Cadmus Group, *Commercial Refrigeration Loadshape Project Final Report*, Northeast Energy Efficiency Partnerships, Regional Evaluation, Measurement, and Verification Forum, Lexington, MA 2015. Page 78, Figure 54.

[2] Derived from average W/hp (758 W/hp ECM, 2088 W/hp SP) multiplied by average HP (1/15). Average watts per horsepower and rated horsepower determined in NEEP Loadshape Report. The Cadmus Group, *Commercial Refrigeration Loadshape Project Final Report*, Northeast Energy Efficiency Partnerships, Regional Evaluation, Measurement, and Verification Forum, Lexington, MA 2015; Page 73, Table 41.

Synchronous motor W/hp is derived using a ratio of average motor efficiencies of the ECM and Synchronous motor types, 0.66 and 0.73 respectively. Oak Ridge National Laboratory, "Q-Sync Motors in Commercial Refrigeration: Preliminary Test Results and Projected benefits", 2015. Page 7, Table 1. For calculation details see reference file "Evaporator Fan Motor Control 2017 Update v2.xlsx".

[3] Based on a 31% to 59% ECM/SP split as reported in the 2016 Vermont Business Sector Market Characterization and Assessment Study, Figure 89, pg. 112.. For the Unknown motor type, the 31% split in motor types uses the average of the two high efficiency motor types ECM and Synchronous. For calculation details see reference file "Evaporator Fan Motor Control 2017 Update v2.xlsx".

[4] Load reduction factor as reported in NEEP Loadshape Report for evaporator fan motor control units. This is the difference in effective runtime of unctrolled motors and the effective runtime of all control styles for motor controls. The Cadmus Group, *Commercial Refrigeration Loadshape Project Final Report*, Northeast Energy Efficiency Partnerships, Regional Evaluation, Measurement, and Verification Forum, Lexington, MA 2015. Page 67, Table 34.

[5] Evaporator fan control unit cost of $520 is referenced from the NEEP Incremental Cost Study Part 4 spreadsheet as listed for the New England region on a per controller cost basis. See reference "Evaporator Fan Controls_NEEP_ICS4 Final June 23 2015.xlsx", "Summary of Results" tab. Per fan cost is estimated to be $91 per fan based an average of 5.7 fans per controller derived from 2016 EVT Evaporator Fan Motor Control installation data. See reference file "Evaporator Fan Motor Control 2017 Update v2.xlsx".

[6] For detailed savings calculations see reference file "Evaporator Fan Motor Control 2017 Update v2.xlsx".

Evaporator Fan Motors

Measure Number: I-E-8 e
Portfolio: EVT TRM Portfolio 2017-11
Status: Active
Effective Date: 2018/1/1
End Date: [None]
Program: Business Energy Services
End Use: Refrigeration

Update Summary

- Measure updated to aggregate characterizations across temperature range and baseline motor for Brushelss DC Motors in both Case Cooler and Walk-In applications.
  - Incorporated participation data through 2016 which made very minor revisions to the Synchrnous motor prescriptive savings due to changes to the weighted averages.
  - Uploaded the revised workbook, "evaporator-motors-reference-2017-v4.xlsx" replacing the older version, "evaporator-motors-reference-2016-v3.xlsx". Updated the references throughout the characterization as well.
  - Made subsequent edits to the Description section, which discuss the reason for the characterization aggregation (adding measure to midstream program) and how the characterization was performed.

Referenced Documents

- The Cadmus Group, Commercial Refrigeration Loadshape Project Final Report, Northeast Energy Efficiency Partnerships, Regional Evaluation, Measurement, and Verification Forum, Lexington, MA 2015.
- Navigant, “Energy Savings Potential and Opportunities for High-Efficiency Electric Motors in Residential and Commercial Equipment”, 2013.
- Oak Ridge National Laboratory, “Q-Sync Motors in Commercial Refrigeration: Preliminary Test Results and Projected benefits”, 2015.
- AESC Inc., “Energy Savings of Permanent Magnet Synchronous Fan Motor Assembly Refrigerated Case Evaporators”, 2016.
- DEER2014-EUL-table-update_2014-02-05.xlsx
- NEEP, "Q-SyncMotors.xlsx", 2016.
- Evaporator Motors Reference 2017_v4

Description

Refrigerator and Freezer walk-in unit evaporator fans typically contain two to twelve evaporator fans that run nearly 24 hours each day, 365 days each year. Not only do these fans use electricity, but the heat that each fan generates must also be removed by the refrigeration system to keep the product cold, adding more to the annual electricity costs. If the cooler or freezer has single-phase power, the electricity usage can be reduced by choosing brushless DC (BDC) motors or permanent magnet synchronous motors (Sync) instead of conventional shaded-pole (SP) and permanent split capacitor (PSC) motors. Brushless DC motors are also known by the copyrighted trade name ECM (Electronically Commutated Motor).

In 2016, synchronous motors have been added to Efficiency Vermont's Upstream Refrigeration Program. Synchronous motors are not tracked through a typical Commercial Refrigeration Rebate Form. Prescriptive savings for synchronous motoros have been estimated using historical Efficiency Vermont data. See reference tables below.

In 2017, brushless permanent magnet motors (also known as ECM) have been added to Efficiency Vermont's EEFM Midstream Program. Similar to sychronous motors, prescriptive savings for BPM motors have been estimated using historical Efficiency Vermont data and aggregated across temperature ranges and replacement/baseline motor.

Algorithms

Electric Demand Savings

$\Delta kW = (kW_{Base} - kW_{Eff}) \times DC_{Evap} \times BF$

$kW_{Base} = W_{Base\_Out} \times (1/\eta_{Base}) / 1000$

$kW_{Eff} = W_{Eff\_Out} \times (1/\eta_{Eff}) / 1000$

Symbol Table

Electric Energy Savings

$\Delta kWh = \Delta kW \times 8760$

Symbol Table

Fossil Fuel Savings

Where:

ΔkW = Gross customer connected load kW savings for the measure (kW)

ΔkWh = Gross customer annual kWh savings for the measure (kWh)

η_{Base} = Baseline motor efficiency, 0.26 for SP/0.40 for PSC[1]

W_{Base_Out} = Rated watt output of baseline motor, 12 watts for cases/42 watts for walk-in applications[2]

η_{Eff} = New motor efficiency, 0.66 for BDC/0.73 for Sync[3]

1000 = Convert watts to kilowatts (W/kW)

8760 = Hours / Year

BF = Bonus factor for reduced cooling load from eliminating heat generated by the evaporator fan inside the cooler or freezer (1.4 for coolers, 1.8 for freezers)[4]

DC_{Evap} = Duty cycle of the evaporator fan, 97.8%[5]

kW_{Base} = Electrical demand of the baseline motor

kW_{Eff} = Electrical demand of the efficient motor

kW_{Eff} =

W_{Eff_Out} = Rated watt output of efficient motor, 12 watts for cases/42 watts for walk-in applications

Baseline Efficiencies

The baseline condition is shaded pole or permanent split capacitor evaporator fan motor.

Efficient Equipment

High efficiency is a brushless DC or synchronous evaporator fan motor.

Operating Hours

A cooler evaporator fan runs all the time or 8760 hours per year. A freezer evaporator fan runs 8550 hours per year due to defrost cycles.[2] The smaller number of hours for freezer fan run time is captured in the duty cycle factor in the ΔkW calculation, so that 100% coincidence factors may be applied to both applications.

Load Shapes

Evaporator fan loadshape was reassessed using results and data from the Cadmus NEEP Loadshape report. For evaluation details see the reference file "Evaporator Motors Reference 2017 v4.xlsx", 'Cadmus Loadshape 2015' tab.

25a Flat (8760 hours)

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
25	Flat (8760 hours)	Active	31.7 %	34.9 %	15.9 %	17.5 %	100.0 %	100.0 %

Net Savings Factors

Measures

RFRBLFAN	Efficient blower fan
RFRSYFAN	Synchronous Motor Evaporator Fan

Tracks [Base Track]

6013PRES [is base track]	Pres Equip Rpl
6013UPST [is base track]	Upstream - Commercial
6014PRES [is base track]	6014PRES

Persistence

The persistence factor is assumed to be one.

Lifetimes

15 years[6]

Measure Cost

Retrofit cost are shown below for brushless DC and synchronous motors applied in both case and walk-in applications.[7]

Evaporator Fan Retrofit Costs

Application	Motor Type	
	Brushless DC	Synchronous
Case	$114	$120
Walk-In	$143	$145

Cost of retrofit includes installation

O&M Cost Adjustments

There are no standard operation and maintenance cost adjustments used for this measure.

Reference Tables

Motor Savings for Evaporator Fans

Measure	Temperature Range	Baseline Motor	Case Cooler		Walk-In Coolers	
			Demand Savings kW/motor	Energy Savings kWh/year	Demand Savings kW/motor	Energy Savings kWh/year
Brushless Permanent Magnet Motor	Low/Medium/High	SP/PSC	0.04	308	0.10	899
Synchronous Motor	Low/Medium/High*	SP/PSC*	0.04	322	0.10	904

*Weighted average Bonus Factor (1.33/1.33) and baseline motor efficiency (0.27/0.31) derived from Efficiency Vermont motor installations for Case/Walk-In applications respectively. See reference file: Evaporator Motors Reference 2017 v4.xlsx.

Footnotes

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[1] Efficiencies were determined using an average of baseline motor efficiencies from the following reports. Navigant, “Energy Savings Potential and Opportunities for High-Efficiency Electric Motors in Residential and Commercial Equipment”, 2013. Page 5, Table 2.1. Oak Ridge National Laboratory, *“Q-Sync Motors in Commercial Refrigeration: Preliminary Test Results and Projected benefits”*, 2015. Page 1, Section 1.

[2] Motor wattage derived using motor type efficiencies and output ratings. Calculated power consumption comparable to NEEP loadshape reported values for baseline walk-in motors. For calculation details see reference file “Evaporator Motors Reference 2017 v4.xlsx”, “Savings Table” tab. NEEP values for reference from The Cadmus Group, *Commercial Refrigeration Loadshape Project Final Report*, Northeast Energy Efficiency Partnerships, Regional Evaluation, Measurement, and Verification Forum, Lexington, MA 2015. Page 87, Section 5.1.4.

[3] Oak Ridge National Laboratory, *“Q-Sync Motors in Commercial Refrigeration: Preliminary Test Results and Projected benefits”*, 2015. Page 1, Section 1.

[4] Bonus factors as derived in the NEEP Refrigeration Loadshape Report. The Cadmus Group, *Commercial Refrigeration Loadshape Project Final Report*, Northeast Energy Efficiency Partnerships, Regional Evaluation, Measurement, and Verification Forum, Lexington, MA 2015. Page 78, Figure 54.

[5] An evaporator fan runs on average 8567 hours per year, 97.8% of the full 8760 hours per year, due to defrost cycles. The Cadmus Group, *Commercial Refrigeration Loadshape Project Final Report*, Northeast Energy Efficiency Partnerships, Regional Evaluation, Measurement, and Verification Forum, Lexington, MA 2015. Page 67, Table 34.

[6] DEER 2014 effective useful life (EUL) estimates. California DEER 2014 Effective Useful Life Table Update, DEER2014-EUL-table-update_2014-02-05.xlsx

[7] Costs are determined from manufacturer quotes and listings. See reference files Evaporator Motors Reference 2017 v4.xlsx, NEEP Incremental Cost Study – Emerging Technology, Q-SyncMotors.xlsx, 2016; AESC Inc., *“Energy Savings of Permanent Magnet Synchronous Fan Motor Assembly Refrigerated Case Evaporators”*, 2016. Page 26.

Efficient Space Heating Systems

Measure Number:	VIII-C-1 c
Portfolio:	EVT TRM Portfolio 2017-10
Status:	Inactive
Effective Date:	2018/1/1
End Date:	2018/12/31
Program:	Commercial Heat and Process Fuels
End Use:	Space Heating

Update Summary

- Update the Baseline efficiency of boilers and furnaces

- Update to MMBTU savings algorithm to account for typical oversizing of units and to replace "(HDD x CF x 24/DT)" with a "FLH" input based on NY TRM commercial FLH values and Vermont building data provide by Cadmus

- General updates to outdated sources, including costs

Referenced Documents

- Boiler Furnace Cost Analysis - FINAL052410
- DEER2014-EUL-table-update_2014-02-05.xlsx
- US DOE, "Technical Support Document for Commercial Packaged Boilers", 2016.
- AHRI Boiler and Furnace Database Data
- EVT_Commercial EFLH_Analysis_July 2017
- EVT_Efficient Space Heating Systems_Costs_Analysis_Oct 2017

Description

This measure applies to oil- and propane-fired boilers and furnaces up to 500 MBH in capacity, used in non-residential and multi-family residential space-heating applications that meet the specified minimum efficiency requirement. Fossil fuel savings are realized due to the higher AFUE or Thermal Efficiency of the qualifying equipment. This measure will provide incentives for market based opportunities, including standard equipment replacement, new equipment purchases, and new construction.

Baseline Efficiencies

Baseline equipment is a new standard efficiency oil- or propane-fired furnace or boiler, used for space heating in a non-residential or multi-family residential application. Baseline efficiencies are detailed below in **Reference Table 1: Baseline Efficiency.**

Efficient Equipment

The installed oil or propane furnace or boiler must have an AFUE or thermal efficiency (Et) that meets program specific requirements be used for space-heating only in a non-residential or multi-family residential installation.

Algorithms

Electric Demand Savings

Electric Energy Savings

Fossil Fuel Savings

$$\Delta \text{MMBTU} = \text{FLH} \times (\text{Capacity} / 1000) \times (1 / \text{OF}) \times (1 / \eta_{\text{Base}} - 1 / \eta_{\text{Eff}})$$

There are no electrical energy or demand algorithms associated with this measure. Electric energy savings from efficient furnace fans included with efficient furnaces are calculated separately.

Where:

ΔMMBTU	=	gross customer annual MMBtu fuel savings for the measure
η_{Base}	=	efficiency of baseline equipment, in AFUE or Thermal Efficiency. See Reference Table 1: Baseline Efficiency
η_{Eff}	=	Actual efficiency of new equipment, in AFUE or Thermal Efficiency.
1000	=	Conversion from MBH to MMBtu/hour
Capacity	=	Capacity of equipment to be installed (in MBH – 1000's of Btu/hr)
FLH	=	Estimated average full load heating hours = 1,062[1]

OF = Oversize Factor is the ratio of heating unit size to actual heating load (assume 1.1)[2]

Load Shapes

N/A

Net Savings Factors

Measures

SHRBFOIL	Replace boiler, fuel oil
SHRBPROP	Replace boiler, propane
SHRFFOIL	Replace furnace, fuel oil
SHRFPROP	Replace furnace, propane

Tracks [Base Track]

6013PRES [is base track]	Pres Equip Rpl
6014PRES [is base track]	6014PRES
6017PRES [is base track]	6017PRES

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Pres Equip Rpl	6013PRES	SHRBFOIL	1.00	1.00
Pres Equip Rpl	6013PRES	SHRBPROP	1.00	1.00
Pres Equip Rpl	6013PRES	SHRFFOIL	1.00	1.00
Pres Equip Rpl	6013PRES	SHRFPROP	1.00	1.00
6014PRES	6014PRES	SHRBFOIL	0.95	1.05
6014PRES	6014PRES	SHRBPROP	0.95	1.05
6014PRES	6014PRES	SHRFFOIL	0.95	1.05
6014PRES	6014PRES	SHRFPROP	0.95	1.05
6017PRES	6017PRES	SHRBFOIL	1.00	1.00
6017PRES	6017PRES	SHRBPROP	1.00	1.00
6017PRES	6017PRES	SHRFFOIL	1.00	1.00
6017PRES	6017PRES	SHRFPROP	1.00	1.00

Lifetimes

Lifetime for boilers and furnaces is 20 years.[3]

Measure Cost

The incremental costs of more efficient equipment are detailed below in Reference Table 2: Measure Costs.

Fossil Fuel Descriptions

See Fossil Fuel Savings algorithms above.

Water Descriptions

There are no water algorithms or default values for this measure.

Reference Tables

Table 1: Baseline Efficiency

Fuel Type	Unit Type	Capacity	Baseline Efficiency[4]
Oil	Boiler	< 300 MBh	82%
		300-500 MBh	82%
	Furnace	< 225 MBh	83%
LP	Boiler	< 300 MBh	81%
		300-500 MBh	81%
	Furnace	< 225 MBh	80%

Table2: Measure Costs[5]

			Baseline Installed	Efficient Installed	Incremental

Fuel Type	Unit Type	Capacity	Cost	Cost	Cost ($ per Btu/h)
Oil	Boiler	< 300 MBh	$7,461	$9,013	$0.0141
		300-500 MBh	$25,326	$30,874	$0.0069
	Furnace	< 225 MBh	$2,309	$2,649	$0.0042
LP	Boiler	< 300 MBh	$6,092	$7,843	$0.0175
		300-500 MBh	$26,266	$40,258	$0.0175
	Furnace	< 225 MBh	$2,175	$2,776	$0.0075

Footnotes

[1] Commercial FLH is a weighted average of commercial FLH values from New York Joint Utiliites,"New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs (Version 4)," April 29, 2016 and Vermont building data provided by Cadmus. See file EVT_Commercial EFLH_Analysis_July 2017 for calculation details.

[2] Oversizing factor determined from US DOE Technical Support Document for Commercial Packaged Boilers (Oversizing Factor = 1.1; 10% larger unit than the required heating load). US Department of Energy, "Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Commercial Packaged Boilers", March 2016. Pg. 7-3 & pg 7-10, Eq. 7.6.

[3] California 2014 DEER Effective Useful Life database. See reference file "DEER2014 EUL Table Update.xlsx".

[4] Lowest efficiency available from AHRI database, except for oil furnaces <225 MBH and LP boilers <300 MBh, which were adjusted upward to better reflect the efficiencies available within those capacity bins. See reference file "AHRI Boiler and Furnace Data.xlsx".

[5] Costs from analysis of DOE cost data from DOE technical support documentation as summarized in file "EVT_Efficient Space Heating Systems_Costs_Analysis_Oct 2017.xls." Baseline costs correspond with the baseline equipment efficiency for each category as listed in the TRM. Efficient costs are an average of the range of efficiency levels for each category available within AHRI data, beginning with the EVT qualifying level. Incremental cost ($ per Btu/hr) was derived using representative equipment capacity values for each category from the relevant DOE Technical Support Document.

ENERGY STAR Dehumidifiers

Measure Number:	IV-D-2 d
Portfolio:	EVT TRM Portfolio 2017-12
Status:	Inactive
Effective Date:	2018/1/1
End Date:	2018/12/31
Program:	Efficient Products Program
End Use:	Appliances

Update Summary

- Incorporated ENERGY STAR Most Efficient tier designation for dehumidifiers, effective 1/1/2018. This designation is only for qualifying products of capacities of 75 pints or less and differentiates between stand alone and whole house options.
    - As a result, made associated revisions to the measure description, reference documents (updated the excel analysis spreadsheet), algorithms, high efficiency specifications, and source notes
- Added a measure code for the most efficient tier units
- Additional updates came after an internal review in the form of removing the varying capacities depicted in the deemed energy and demand savings tables. For added detail, please see reviewer's notes.

Referenced Documents

- ENERGY STAR_Dehumidifiers_V4 0_Specification_Final
- Dehumidifiers ENERGY STAR Most Efficient 2018 Final Criteria
- DOE Energy Conservation Standards for Dehumidifiers, July 2012
- ENERGY STAR Dehumidifier V6 EVT TRM Analysis

Description

A dehumidifier meeting the new minimum qualifying efficiency standard established by ENERGY STAR Program (Version 4.0), effective 10/25/2016, and ENERGY STAR Most Effecient 2018 Criteria, effective, 01/01/2018, is purchased and installed in a residential setting in place of a unit that meets the minimum federal standard efficiency.

Algorithms

Electric Demand Savings

Demand Savings (ΔkW)		
ENERGY STAR	ENERGY STAR Most Efficient: Stand Alone	ENERGY STAR Most Efficient: Whole House
0.140	0.192	0.214

ΔkW = ΔkWh/Hours

Symbol Table

Electric Energy Savings

Energy Savings (ΔkWh)		
ENERGY STAR	ENERGY STAR Most Efficient: Stand Alone	ENERGY STAR Most Efficient: Whole House
229	313	350

ΔkWh = (((Avg Capacity × 0.473) / 24) × Hours) × (1 / (L/kWh_Base) – 1 / (L/kWh_Eff))

Where:

ΔkW = ΔkWh / Hours

ΔkWh = gross customer annual kWh savings for the measure

0.473 = Constant to convert Pints to Liters

24 = Constant to convert Liters/day to Liters/hour

Avg Capacity = Average capacity of the unit (pints/day)
57.6[2]

Hours = Run hours per year
= 1632[1]

L/kWh_Base = Baseline unit liters of water per kWh consumed, as provided in tables above
1.60[3]

L/kWh_Eff = Efficient unit liters of water per kWh consumed, as provided in tables above
ENERGY STAR = 2.00[4]
ENERGY STAR Most Efficient: Stand Alone = 2.20 [5]
ENERGY STAR Most Efficient: Whole House = 2.30 [5]

Baseline Efficiencies

Baseline efficiency is a dehumidifier that meets the Federal Standard efficiency standards as defined below[6]:

Capacity (pints/day)	**Federal Standard Criteria (L/kWh)**
≤35	≥1.35
> 35 to ≤45	≥1.50
> 45 to ≤ 54	≥1.60
> 54 to ≤ 75	≥1.70
> 75 to ≤ 185	≥2.50

High Efficiency

High efficiency is defined as any model meeting or exceeding ENERGY STAR qualifying efficiency standard established by the current ENERGY STAR (Version 4.0). The Most Efficient Tier was included by ENERGY STAR and made effective on 01/01/2018. As defined by ENERGY STAR, a stand alone dehumidifier is defined as a portable unit designed to provide dehumidification within the confined living space where it is placed and plugged into an electrical outlet. And a whole house dehumidifier is a unit designed to be incorporated into the home's HVAC system, or installed with its own duct system, and provide dehumidification for all conditioned spaces within the building enclosure.

Performance Criteria for ENERGY STAR Qualified Dehumidifiers:

Product Capacity	ENERGY STAR Energy Factor	ENERGY STAR Most Efficient: Stand Alone Energy Factor	ENERGY STAR Most Efficient: Whole House Energy Factor
(Pints/Day)	(L/kWh)	(L/kWh)	(L/kWh)
< 75	≥ 2.00	≥ 2.20	≥ 2.30
75 ≤ 185	≥ 2.80	N/A	N/A

Load Shapes

73a Residential - Dehumidifier

Number	**Name**	**Status**	**Winter On kWh**	**Winter Off kWh**	**Summer On kWh**	**Summer Off kWh**	**Winter kW**	**Summer kW**
73	Residential - Dehumidifier	Active	15.9 %	17.5 %	31.7 %	34.9 %	0.0 %	35.3 %

Net Savings Factors

Measures

ACEDEHUM	Dehumidifier
ACEDHUME	Residential dehumidifier ENERGY STAR Most Efficient tier

Tracks [Base Track]

6032EPEP [is base track]	Efficient Products - Residential

Track Name	**Track Nr.**	**Measure Code**	**Free Rider**	**Spill Over**
Efficient Products - Residential	6032EPEP	ACEDEHUM	0.77	1.00
Efficient Products - Residential	6032EPEP	ACEDHUME	0.95	1.05

Persistence

The persistence factor is assumed to be one.

Lifetimes

12 years[7]

Analysis period is the same as the lifetime.

Measure Cost

The incremental capital cost for a measure meeting or exceeding the ENERGY STAR criteria is $9.52[8]

The incremental capital cost for a measure meeting or exceeding the ENERGY STAR Most Efficient criteria is $75 [9]

O&M Cost Adjustments

There are no operation and maintenance cost adjustments for this measure

Fossil Fuel Description

There are no fossil-fuel algorithms or default values for this measure.

Footnotes

[1] Based on 68 days of 24 hour operation; ENERGY STAR Dehumidifier Calculator http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/appliance_calculator.xlsx?f3f7-6a8b&f3f7-6a8b

[2] Average Water Removal Capacity (pints/day) from all units Energy Star QPL. Refer to Savings Calc tab of the analysis document: of ENERGY STAR Dehumidifier V6 EVT TRM Analysis.xlsx.

[3] Weighted average from Energy Star QPL. Refer to Savings Calc tab of analysis document: of ENERGY STAR Dehumidifier V6 EVT TRM Analysis.xlsx.

[4] Average L/kWh based on Weighted average of units in each bin. Refer to Savings Calc tab of analysis document: of ENERGY STAR Dehumidifier V6 EVT TRM Analysis.xlsx.

[5] As sourced from ENERGY STAR Most Efficient 2018 Criteria for Dehumidifiers, effective 01/01/2018

[6] The Federal Standard for Dehumidifiers changed as of October 2012; https://www.federalregister.gov/articles/2010/12/02/2010-29756/energy-conservation-program-for-consumer-products-test-procedures-for-residential-dishwashers#h-11

[7] ENERGY STAR Dehumidifier Calculator http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/appliance_calculator.xlsx?f3f7-6a8b&f3f7-6a8b

[8] Based on incremental costs from 2016 ENERGY STAR Appliance Calculator. Refer to weighted average calculation on Savings Calc tab of ENERGY STAR Dehumidifier V6 EVT TRM Analysis.xlsx.

[9] DOE Energy Conservation Standards for Residential Dehumidifiers, Appliance and Equipment Standard, 10 CFR Part 430, July 23, 2012, page 73. The sourced table is an analysis on the incremental manufacturer production costs on dehumidifiers with varying incentive levels. Assuming the markup costs between the baseline units and the most efficient units are equal. The final incremental cost reproduced above is a straight average of all the dehumidifiers, both stand alone and whole house, with an efficiency level meeting or exceeding ENERGY STAR's Most Efficient criteria. Opted to combine the incremental cost into one value because the stand alone and whole house incremental costs were near idential.

Efficient Clothes Washers

Measure Number:	IV-A-1 q
Portfolio:	EVT TRM Portfolio 2017-09
Status:	Inactive
Effective Date:	2018/1/1
End Date:	2018/12/31
Program:	Efficient Products Program
End Use:	Clothes Washing

Applicable Markets

Applicable Markets
Efficient Products
Residential New Construction
Multifamily In Unit New Construction
Multifamily In Unit Retrofit
Low Income Single Family Retrofit
Existing Homes Retrofit

Update Summary

Update to this characterization consists of:

- Updated to reflect new Federal Clothes Washer manufacturing standards (as of 1/1/2018), resulting in higher baseline efficency levels for top loading machines.
- Updated to reflect new ENERGY STAR specifications (as of 2/5/2018), resulting in new efficient product efficiency levels for Front Loading units. Note we are assuming an effective date of 1/1/2018.
- Updated % Energy Use allocation based on most recent DOE Life-Cycle Cost and Payback Period Excel-based analytical tool.
- Updated %DHW and %Dryer assumptions based on data received 08/21/2017 from the upcoming NMR Vermont Residential Market Assessment study.
- Updated market share assumptions based on available product on California Energy Commission Appliance Database. Note many front loading units that were previously ENERGY STAR are now baseline, which significantly alters the share.
- Updated costs based on most recent DOE Life-Cycle Cost and Payback Period Excel-based analytical tool and new efficiency assumptions.

Referenced Documents

- Copy of EERE-2008-BT-STD-0019-0043
- 2018 Clothes washer savings_04032018

Description

A new clothes washer exceeding minimum qualifying efficiency standards established as ENERGY STAR/CEE Tier 1, CEE Tier 2 or CEE Advanced Tier as of 1/1/2018, as defined below is purchased, installed in new construction (Market Opportunity) or is installed within an existing home having incentivized the early replacement of an inefficient unit (Early Replacement):

Efficiency Level	**Integrated Modified Energy Factor (IMEF)**		**Integrated Water Factor (IWF)**	
	Front Loading	Top Loading	Front Loading	Top Loading
ENERGY STAR	>= 2.76	>= 2.06	<= 3.2	<= 4.3
CEE TIER 2	>= 2.92	n/a	<= 3.2	n/a
CEE ADVANCED TIER	>= 3.1	n/a	<= 3.0	n/a

The Integrated Modified Energy Factor (IMEF) measures energy consumption of the total laundry cycle (unit operation, washing and drying) and the per-cycle standby and off mode energy consumption; the higher the number, the greater the efficiency.

The Integrated Water Factor (IWF) is the number of gallons needed for each cubic foot of laundry. A lower number indicates lower consumption and more efficient use of water.

Baseline Efficiencies

Market Opportunity:

The baseline efficiency is determined according to the Integrated Modified Energy Factor (IMEF) that takes into account the energy and water required per clothes washer cycle, including energy required by the clothes dryer per clothes washer cycle and standby/off mode consumption. The Federal baseline IMEF as of January 2018 is 1.84 for front loading units and 1.57 for top loading units.

Early Replacement Baseline:

The baseline in this case is the efficiency of the existing unit for its assumed remaining life (3 years) and the new baseline as defined above for the remainder of the measure (remaining 11 years). Eligibility for this measure is limited to pre-2004 non-Energy Star units. The Federal baseline for clothes washers prior to 2004 was 0.817 MEF, and the average value of units tested in a 2001 DOE market assessment was 1.164MEF. Converting MEF to IMEF using an ENERGY STAR conversion tool copied in to the reference calculation spreadsheet "2018 Clothes Washer Savings.xls", provides the assumption for existing units of 0.74 IMEF for top-loading and 0.91 IMEF for front loading machines.

Efficient Equipment

High efficiency is defined as any model meeting or exceeding ENERGY STAR, CEE Tier 2 or CEE Advanced Tier standards as of 2/5/2018, as provided in table above.

Algorithms

Electric Demand Savings

ΔkW = ΔkWh/Hours

Symbol Table

Electric Energy Savings

ΔkWh = (Capacity × 1/IMEFbase × Ncycles × (%CWbase + (%DHWbase × %Electric_DHW) + (%Dryerbase × %Electric_Dryer))) - (Capacity × 1/IMEFeff × Ncycles × (%CWeff + (%DHWeff × %Electric_DHW) + (%Dryereff × %Electric_Dryer)))

Symbol Table

Fossil Fuel Savings

ΔMMBtu = ((Capacity × 1/IMEFbase × Ncycles × ((%DHWbase × %Fuel_DHW × R_eff) + (%Dryerbase × %Fuel_Dryer))) - (Capacity × 1/IMEFeff × Ncycles × ((%DHWeff × %Fuel_DHW× R_eff) + (%Dryereff × %Fuel_Dryer))))× MMBtu_convert

Symbol Table

Water Savings

ΔWater (CCF) = ((Capacity × (IWFbase - IWFeff)) × Ncycles) / GallonsPerCCF

Where:

%CWbase = = Percentage of total energy consumption for baseline Clothes Washer operation (Deemed, dependent on efficiency level – see table below)

%CWef = = Percentage of total energy consumption for efficient Clothes Washer operation (Deemed, dependent on efficiency level – see table below)

%DHWbase = = Percentage of total energy consumption used for water heating by baseline unit (Deemed, dependent on efficiency level – see table below)

%DHWeff = = Percentage of total energy consumption used for water heating by efficient unit (Deemed, dependent on efficiency level – see table below)

%Dryerbase = = Percentage of total baseline energy consumption for dryer operation (Deemed, dependent on efficiency level – see table below)

%Dryereff = = Percentage of total efficient energy consumption for dryer operation (Deemed, dependent on efficiency level – see table below)

	Percentage of Total Energy Consumption[2]		
	%CW	**%DHW**	**%Dryer**
Federal Standard	8%	20%	72%
ENERGY STAR	5%	25%	70%
CEE TIER 2	10%	3%	87%
Advanced Tier	10%	3%	87%

%Electric_DHW = = Percentage of DHW savings assumed to be electric (Deemed, dependent on market)

Market	%Electric_DHW[3]
Efficient Products	25.0%
RNC	24% if unknown
Multifamily New Construction and Retrofit	Assumed always known

%Electric_Dryer = = Percentage of dryer savings assumed to be electric (Deemed, dependent on market)

Market	%Electric_Dryer[3]
Efficient Products	74.0%
RNC	76% if unknown
Multifamily New Construction and Retrofit	Assumed always known

%Fuel_DHW = = Percentage of DHW savings assumed to be non electric [3] (Deemed, dependent on market)

Market	DHW Fuel	%Fuel_DHW
Efficient Products	Natural Gas	26%
	Propane	27%
	Oil	20%
RNC	Natural Gas	14%
	Propane	52%
	Oil	10%
Multifamily New Construction and Retrofit	Assumed always known	

%Fuel_Dryer = = Percentage of dryer savings assumed to be Natural Gas[3]

(Deemed, dependent on market)

Market	Dryer fuel	%Gas_Dryer
Efficient Products	Natural Gas	11%
	LP Gas	15%
RNC	Natural Gas	8%
	LP Gas	16%
Multifamily New Construction	Assumed always known	

ΔkW = = gross customer connected load kW savings for the measure (Output)

ΔkWh = gross customer annual kWh savings for the measure (Output)

ΔMMBtu = = gross customer annual MMBtu savings for the measure (Output)

ΔWater (CCF) = = gross customer annual water savings for the measure (Output)

Capacity = = Clothes Washer capacity (cubic feet

= 3.58 [4] (Deemed)

GallonsPerCCF = Gallons per CCF

=748

Hours = = assumed annual run hours of clothes washer (Deemed, dependent on market)

Market	Hours[1]
Single Family – Efficient Products, RNC	322
Multifamily	265

IMEFbase = = Integrated Modified Energy Factor of baseline unit

= Values provided in table below; Federal Standard for Market Opportunity and Existing Unit for Early Replacement (Deemed, dependent on application)

IMEFeff = =Integrated Modified Energy Factor of efficient unit

= Values provided in table below (Deemed, dependent on efficiency level)

IWFbase = = Integrated Water Factor of baseline clothes washer

= Values provided below; Federal Standard for Market Opportunity and Existing Unit for Early Replacement (Deemed, dependent on application)

IWFeff = =Integrated Water Factor of efficient unit

= Values provided in table below (Deemed, dependent on efficiency level)

MMBtu_convert = = Convertion factor from kWh to MMBtu (Constant)

= 0.003413

Ncycles = = Number of Cycles per year (Deemed, dependent on market)

Market	Ncycles
Single Family – Efficiency Products, RNC	322[5]
Multifamily	265[6]

R_eff = = Recovery efficiency factor (Deemed)

= 1.26[7]

Load Shapes

9a Residential Clothes Washer

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
9	Residential Clothes Washer	Active	42.0 %	28.8 %	16.9 %	12.3 %	4.4 %	3.3 %

Net Savings Factors

Measures

CKLESWRP	Energy Star washer
CKLESWER	Energy Star washer, early replacement
CKLT2WER	Energy Star Clothes Washer CEE 2 Early Replacement
CKLT3WER	Energy Star Clothes Washer CEE 3 Early Replacement
CKLC2WRP	Energy Star clothes washer CEE Tier 2
CKLC3WRP	Energy Star clothes washer CEE Tier 3

Tracks [Base Track]

6018LINC [is base track]	LIMF NC
6019MFNC [is base track]	MF Mkt NC
6032EPEP [is base track]	Efficient Products - Residential
6034LISF [is base track]	LISF Retrofit
6036RETR [is base track]	Res Retrofit
6038VESH [is base track]	RNC VESH
6017PRES [is base track]	6017PRES
6020PRES [is base track]	6020PRES

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
LIMF NC	6018LINC	CKLESWRP	1.00	1.00
LIMF NC	6018LINC	CKLESWER	1.00	1.00
LIMF NC	6018LINC	CKLT2WER	1.00	1.00
LIMF NC	6018LINC	CKLT3WER	1.00	1.00
LIMF NC	6018LINC	CKLC2WRP	1.00	1.00
LIMF NC	6018LINC	CKLC3WRP	1.00	1.00
MF Mkt NC	6019MFNC	CKLESWRP	0.95	1.00
MF Mkt NC	6019MFNC	CKLESWER	0.95	1.00
MF Mkt NC	6019MFNC	CKLT2WER	0.95	1.20
MF Mkt NC	6019MFNC	CKLT3WER	0.95	1.20
MF Mkt NC	6019MFNC	CKLC2WRP	0.95	1.00
MF Mkt NC	6019MFNC	CKLC3WRP	0.95	1.00
Efficient Products - Residential	6032EPEP	CKLESWRP	0.50	1.00
Efficient Products - Residential	6032EPEP	CKLESWER	0.95	1.00
Efficient Products - Residential	6032EPEP	CKLT2WER	0.95	1.20
Efficient Products - Residential	6032EPEP	CKLT3WER	0.95	1.20
Efficient Products - Residential	6032EPEP	CKLC2WRP	0.50	1.00

Efficient Products - Residential	6032EPEP	CKLC3WRP	0.90	1.10
LISF Retrofit	6034LISF	CKLESWRP	1.00	1.00
LISF Retrofit	6034LISF	CKLESWER	1.00	1.00
LISF Retrofit	6034LISF	CKLT2WER	1.00	1.00
LISF Retrofit	6034LISF	CKLT3WER	1.00	1.00
LISF Retrofit	6034LISF	CKLC2WRP	1.00	1.00
LISF Retrofit	6034LISF	CKLC3WRP	1.00	1.00
Res Retrofit	6036RETR	CKLESWRP	0.90	1.00
Res Retrofit	6036RETR	CKLESWER	0.90	1.00
Res Retrofit	6036RETR	CKLT2WER	0.90	1.00
Res Retrofit	6036RETR	CKLT3WER	0.90	1.00
Res Retrofit	6036RETR	CKLC2WRP	0.90	1.00
Res Retrofit	6036RETR	CKLC3WRP	0.90	1.00
RNC VESH	6038VESH	CKLESWRP	0.95	1.20
RNC VESH	6038VESH	CKLESWER	0.95	1.00
RNC VESH	6038VESH	CKLT2WER	0.95	1.20
RNC VESH	6038VESH	CKLT3WER	0.95	1.20
RNC VESH	6038VESH	CKLC2WRP	0.95	1.20
RNC VESH	6038VESH	CKLC3WRP	0.95	1.20
6017PRES	6017PRES	CKLESWRP	1.00	1.00
6017PRES	6017PRES	CKLESWER	1.00	1.00
6017PRES	6017PRES	CKLT2WER	1.00	1.00
6017PRES	6017PRES	CKLT3WER	1.00	1.00
6017PRES	6017PRES	CKLC2WRP	1.00	1.00
6017PRES	6017PRES	CKLC3WRP	1.00	1.00
6020PRES	6020PRES	CKLESWRP	0.90	1.00
6020PRES	6020PRES	CKLESWER	0.90	1.00
6020PRES	6020PRES	CKLT2WER	0.90	1.00
6020PRES	6020PRES	CKLT3WER	0.90	1.00
6020PRES	6020PRES	CKLC2WRP	0.90	1.00
6020PRES	6020PRES	CKLC3WRP	0.90	1.00

Lifetimes

14 years[8](same as DPS screening of Efficiency Utility program).

Analysis period is the same as the lifetime. Early Replacement: The existing unit is assumed to have a remaining life of 3 years.

Measure Cost

The incremental cost for this measure is provided in the table below[9]:

Efficiency Level	Market Opportunity Incremental Cost	Early Replacement Full Install Cost
ENERGY STAR	$124	$1,263
CEE TIER 2	$170	$1,309
CEE Advanced Tier	$179	$1,318

For early replacement measures, the deferred baseline replacement cost that would have been incurred after 3 years had the existing unit not been replaced is assumed to be $1,139.

Prescriptive Savings Tables

The following tables provide the Prescriptive Savings values. See ‘2018 Clothes Washer Analysis_04032018.xls’ for details.

kWh Savings

Market Opportunity:

The prescriptive kWH savings based on values provided above where DHW and Dryer fuels are unknown is provided below[10]:

Efficiency Level	Efficient Products ΔkWH			RNC ΔkWH		
	Front	Top	Weighted Average	Front	Top	Weighted Average
ENERGY STAR	103.1	82.4	88.1	103.7	84.6	89.9

CEE TIER 2	120.3	n/a	120.3	121.3	n/a	121.3
CEE ADVANCED TIER	137.6	n/a	137.6	138.9	n/a	138.9

The unit specific kWh savings when DHW and Dryer fuels are known is provided below:

Efficiency Level	Dryer/DHW Fuel Combo	**RNC ΔkWH**			**Multifamily New Construction In Unit ΔkWH**		
		Front	**Top**	**Weighted Average**	**Front**	**Top**	**Weighted Average**
ENERGY STAR	Electric Dryer/Electric DHW	212.8	70.9	110.2	174.9	58.2	90.5
	Electric Dryer/Fuel DHW	96.5	116.3	110.8	79.3	95.5	91.0
	Fuel Dryer/Electric DHW	126.4	-15.9	23.5	103.8	-13.1	19.3
	Fuel Dryer/Fuel DHW	10.1	29.5	24.1	8.3	24.3	19.8
CEE TIER 2	Electric Dryer/Electric DHW	235.7	n/a	235.7	193.7	n/a	193.7
	Electric Dryer/Fuel DHW	118.8	n/a	118.8	97.6	n/a	97.6
	Fuel Dryer/Electric DHW	129.3	n/a	129.3	106.2	n/a	106.2
	Fuel Dryer/Fuel DHW	12.3	n/a	12.3	10.1	n/a	10.1
CEE ADVANCED TIER	Electric Dryer/Electric DHW	258.6	n/a	258.6	212.5	n/a	212.5
	Electric Dryer/Fuel DHW	141.0	n/a	141.0	115.9	n/a	115.9
	Fuel Dryer/Electric DHW	132.2	n/a	132.2	108.6	n/a	108.6
	Fuel Dryer/Fuel DHW	14.6	n/a	14.6	12.0	n/a	12.0

Early Replacement:

The first year savings are provided below, with a mid life adjustment to be applied after 3 years to bring the savings in line with a new replacement as provided above[11]:

Efficiency Level	**Dryer/DHW Fuel Combo**	**Single Family Early Replacement ΔkWH Replacing:**		**Multifamily In Unit Early Replacement ΔkWH Replacing:**		**Mid Life Adjustment Replacing:**	
		Front	**Top**	**Front**	**Top**	**Front**	**Top**
ENERGY STAR	Electric Dryer/Electric DHW	746.5	1037.5	613.3	852.5	15%	11%
	Electric Dryer/Fuel DHW	629.3	537.6	517.1	441.7	18%	21%
	Fuel Dryer/Electric DHW	195.5	525.0	160.6	431.4	12%	4%
	Fuel Dryer/Fuel DHW	78.4	25.1	64.4	20.6	31%	96%
CEE TIER 2	Electric Dryer/Electric DHW	872.0	1163.0	716.5	955.6	27%	20%
	Electric Dryer/Fuel DHW	637.3	545.5	523.6	448.2	19%	22%
	Fuel Dryer/Electric DHW	301.3	630.8	247.5	518.3	43%	20%
	Fuel Dryer/Fuel DHW	66.6	13.3	54.7	10.9	19%	93%
CEE ADVANCED TIER	Electric Dryer/Electric DHW	894.9	1185.9	735.3	974.4	29%	22%
	Electric Dryer/Fuel DHW	659.6	567.8	541.9	466.6	21%	25%
	Fuel Dryer/Electric DHW	304.2	633.7	249.9	520.7	43%	21%
	Fuel Dryer/Fuel DHW	68.8	15.6	56.5	12.8	21%	94%

kW Savings:

Market Opportunity:

The prescriptive kW savings based on values provided above where DHW and Dryer fuels are unknown is provided below:

Efficiency Level	**Efficient Products ΔkW**			**RNC ΔkW**		
	Front	**Top**	**Weighted Average**	**Front**	**Top**	**Weighted Average**
ENERGY STAR	0.320	0.256	0.274	0.322	0.263	0.279
CEE TIER 2	0.374	n/a	0.374	0.377	n/a	0.377
CEE ADVANCED TIER	0.427	n/a	0.427	0.431	n/a	0.431

The unit specific kW savings when DHW and Dryer fuels are known is provided below:

Efficiency Level	**Dryer/DHW Fuel Combo**	**RNC ΔkW**			**Multifamily New Construction In Unit ΔkW**		
		Front	**Top**	**Weighted Average**	**Front**	**Top**	**Weighted Average**
ENERGY STAR	Electric Dryer/Electric DHW	0.661	0.220	0.342	0.661	0.220	0.342
	Electric Dryer/Fuel DHW	0.300	0.361	0.344	0.300	0.361	0.344
	Fuel Dryer/Electric DHW	0.393	-0.049	0.073	0.393	-0.049	0.073
	Fuel Dryer/Fuel DHW	0.031	0.092	0.075	0.031	0.092	0.075
CEE TIER 2	Electric Dryer/Electric DHW	0.732	n/a	0.732	0.732	n/a	0.732
	Electric Dryer/Fuel DHW	0.369	n/a	0.369	0.369	n/a	0.369
	Fuel Dryer/Electric DHW	0.402	n/a	0.402	0.402	n/a	0.402
	Fuel Dryer/Fuel DHW	0.038	n/a	0.038	0.038	n/a	0.038
CEE ADVANCED TIER	Electric Dryer/Electric DHW	0.803	n/a	0.803	0.803	n/a	0.803
	Electric Dryer/Fuel DHW	0.438	n/a	0.438	0.438	n/a	0.438
	Fuel Dryer/Electric DHW	0.411	n/a	0.411	0.411	n/a	0.411
	Fuel Dryer/Fuel DHW	0.045	n/a	0.045	0.045	n/a	0.045

Early Replacement:

The first year savings are provided below, with the mid life adjustment specified in the kWh table to be applied after 3 years to bring the savings in line with a new replacement as provided above:

Efficiency Level	Dryer/DHW Fuel Combo	Single Family Early Replacement ΔkW Replacing:		Multifamily In Unit Early Replacement ΔkW Replacing:	
		Front	Top	Front	Top
ENERGY STAR	Electric Dryer/Electric DHW	2.319	3.223	2.319	3.223
	Electric Dryer/Fuel DHW	1.955	1.670	1.955	1.670
	Fuel Dryer/Electric DHW	0.607	1.631	0.607	1.631
	Fuel Dryer/Fuel DHW	0.243	0.078	0.243	0.078
CEE TIER 2	Electric Dryer/Electric DHW	2.709	3.613	2.709	3.613
	Electric Dryer/Fuel DHW	1.980	1.695	1.980	1.695
	Fuel Dryer/Electric DHW	0.936	1.959	0.936	1.959
	Fuel Dryer/Fuel DHW	0.207	0.041	0.207	0.041
CEE ADVANCED TIER	Electric Dryer/Electric DHW	2.780	3.684	2.780	3.684
	Electric Dryer/Fuel DHW	2.049	1.764	2.049	1.764
	Fuel Dryer/Electric DHW	0.945	1.968	0.945	1.968
	Fuel Dryer/Fuel DHW	0.214	0.048	0.214	0.048

MMBTU Savings:

Market Opportunity:

The prescriptive MMBtu savings where DHW and Dryer fuels are unknown is provided below:

Efficiency Level	Configuration	Efficient Products ΔMMBtu			RNC ΔMMBtu		
		NG	LP	Oil	NG	LP	Oil
ENERGY STAR	Front	0.16	0.18	0.10	0.09	0.31	0.05
	Top	-0.02	-0.01	-0.04	0.00	-0.05	-0.02
	Weighted Average	0.03	0.04	0.00	0.02	0.05	0.00
CEE TIER 2	Front	0.17	0.19	0.10	0.10	0.32	0.05
	Top	n/a	n/a	n/a	n/a	n/a	n/a
	Weighted Average	0.17	0.19	0.10	0.10	0.32	0.05
CEE ADVANCED TIER	Front	0.18	0.20	0.10	0.11	0.33	0.05
	Top	n/a	n/a	n/a	n/a	n/a	n/a
	Weighted Average	0.18	0.20	0.10	0.11	0.33	0.05

The unit specific MMBtu savings when DHW and Dryer fuels are known is provided below:

Efficiency Level	Configuration	Fuel Claimed	RNC ΔMMBtu			Multifamily New Construction In Unit ΔMMBtu		
			Front	Top	Weighted Average	Front	Top	Weighted Average
ENERGY STAR	Electric Dryer/Electric DHW	n/a	0.00	0.00	0.00	0.00	0.00	0.00
	Electric Dryer/Propane DHW	Propane	0.50	-0.20	0.00	0.41	-0.16	0.00
	Electric Dryer/Natural Gas DHW	Natural Gas	0.50	-0.20	0.00	0.41	-0.16	0.00
	Electric Dryer/Oil DHW	Oil	0.50	-0.20	0.00	0.41	-0.16	0.00
	Propane Dryer/Electric DHW	Propane	0.29	0.30	0.30	0.24	0.24	0.24
	Propane Dryer/Propane DHW	Propane	0.80	0.10	0.29	0.65	0.08	0.24
	Propane Dryer/Oil DHW	Oil	0.80	0.10	0.29	0.65	0.08	0.24
	Natural Gas Dryer/Electric DHW	Natural Gas	0.29	0.30	0.30	0.24	0.24	0.24
	Natural Gas Dryer/Natural Gas DHW	Natural Gas	0.80	0.10	0.29	0.65	0.08	0.24
	Natural Gas Dryer/Oil DHW	Oil	0.80	0.10	0.29	0.65	0.08	0.24
CEE TIER 2	Electric Dryer/Electric DHW	n/a	0.00	n/a	0.00	0.00	n/a	0.00
	Electric Dryer/Propane DHW	Propane	0.50	n/a	0.50	0.41	n/a	0.41
	Electric Dryer/Natural Gas DHW	Natural Gas	0.50	n/a	0.50	0.41	n/a	0.41
	Electric Dryer/Oil DHW	Oil	0.50	n/a	0.50	0.41	n/a	0.41
	Propane Dryer/Electric DHW	Propane	0.36	n/a	0.36	0.30	n/a	0.30
	Propane Dryer/Propane DHW	Propane	0.87	n/a	0.87	0.71	n/a	0.71
	Propane Dryer/Oil DHW	Oil	0.87	n/a	0.87	0.71	n/a	0.71
	Natural Gas Dryer/Electric DHW	Natural Gas	0.36	n/a	0.36	0.30	n/a	0.30
	Natural Gas Dryer/Natural Gas DHW	Natural Gas	0.87	n/a	0.87	0.71	n/a	0.71
	Natural Gas Dryer/Oil DHW	Oil	0.87	n/a	0.87	0.71	n/a	0.71
CEE ADVANCED TIER	Electric Dryer/Electric DHW	n/a	0.00	n/a	0.00	0.00	n/a	0.00
	Electric Dryer/Propane DHW	Propane	0.51	n/a	0.51	0.42	n/a	0.42
	Electric Dryer/Natural Gas DHW	Natural Gas	0.51	n/a	0.51	0.42	n/a	0.42
	Electric Dryer/Oil DHW	Oil	0.51	n/a	0.51	0.42	n/a	0.42
	Propane Dryer/Electric DHW	Propane	0.43	n/a	0.43	0.35	n/a	0.35
	Propane Dryer/Propane DHW	Propane	0.94	n/a	0.94	0.77	n/a	0.77
	Propane Dryer/Oil DHW	Oil	0.94	n/a	0.94	0.77	n/a	0.77
	Natural Gas Dryer/Electric DHW	Natural Gas	0.43	n/a	0.43	0.35	n/a	0.35
	Natural Gas Dryer/Natural Gas DHW	Natural Gas	0.94	n/a	0.94	0.77	n/a	0.77
	Natural Gas Dryer/Oil DHW	Oil	0.94	n/a	0.94	0.77	n/a	0.77

Early Replacement:

The first year savings are provided below, with a mid life adjustment to be applied after 3 years to bring the savings in line with a new replacement as provided above:

Efficiency Level	Configuration	Fuel Claimed	Single Family Early Replacement ΔMMBtu Replacing:		Multifamily In Unit Early Replacement ΔMMBtu Replacing:		Mid Life Adjustment Replacing:	
			Front	Top	Front	Top	Front	Top

ENERGY STAR	Electric Dryer/Electric DHW	n/a	0.00	0.00	0.00	0.00	n/a	n/a
	Electric Dryer/Propane DHW	Propane	0.50	2.15	0.41	1.77	-1%	0%
	Electric Dryer/Natural Gas DHW	Natural Gas	0.50	2.15	0.41	1.77	-1%	0%
	Electric Dryer/Oil DHW	Oil	0.50	2.15	0.41	1.77	-1%	0%
	Propane Dryer/Electric DHW	Propane	1.88	1.75	1.55	1.44	16%	17%
	Propane Dryer/Propane DHW	Propane	2.38	3.90	1.96	3.20	12%	8%
	Propane Dryer/Oil DHW	Oil	2.38	3.90	1.96	3.20	12%	8%
	Natural Gas Dryer/Electric DHW	Natural Gas	1.88	1.75	1.55	1.44	16%	17%
	Natural Gas Dryer/Natural Gas DHW	Natural Gas	2.38	3.90	1.96	3.20	12%	8%
	Natural Gas Dryer/Oil DHW	Oil	2.38	3.90	1.96	3.20	12%	8%
CEE TIER 2	Electric Dryer/Electric DHW	n/a	0.00	0.00	0.00	0.00	n/a	n/a
	Electric Dryer/Propane DHW	Propane	1.01	2.66	0.83	2.18	50%	19%
	Electric Dryer/Natural Gas DHW	Natural Gas	1.01	2.66	0.83	2.18	50%	19%
	Electric Dryer/Oil DHW	Oil	1.01	2.66	0.83	2.18	50%	19%
	Propane Dryer/Electric DHW	Propane	1.95	1.82	1.60	1.49	19%	20%
	Propane Dryer/Propane DHW	Propane	2.96	4.47	2.43	3.67	29%	19%
	Propane Dryer/Oil DHW	Oil	2.96	4.47	2.43	3.67	29%	19%
	Natural Gas Dryer/Electric DHW	Natural Gas	1.95	1.82	1.60	1.49	19%	20%
	Natural Gas Dryer/Natural Gas DHW	Natural Gas	2.96	4.47	2.43	3.67	29%	19%
	Natural Gas Dryer/Oil DHW	Oil	2.96	4.47	2.43	3.67	29%	19%
CEE ADVANCED TIER	Electric Dryer/Electric DHW	n/a	0.00	0.00	0.00	0.00	n/a	n/a
	Electric Dryer/Propane DHW	Propane	1.01	2.66	0.83	2.18	50%	19%
	Electric Dryer/Natural Gas DHW	Natural Gas	1.01	2.66	0.83	2.18	50%	19%
	Electric Dryer/Oil DHW	Oil	1.01	2.66	0.83	2.18	50%	19%
	Propane Dryer/Electric DHW	Propane	2.02	1.88	1.66	1.55	21%	23%
	Propane Dryer/Propane DHW	Propane	3.03	4.54	2.49	3.73	31%	21%
	Propane Dryer/Oil DHW	Oil	3.03	4.54	2.49	3.73	31%	21%
	Natural Gas Dryer/Electric DHW	Natural Gas	2.02	1.88	1.66	1.55	21%	23%
	Natural Gas Dryer/Natural Gas DHW	Natural Gas	3.03	4.54	2.49	3.73	31%	21%
	Natural Gas Dryer/Oil DHW	Oil	3.03	4.54	2.49	3.73	31%	21%

Water Savings:

Market Opportunity:

The prescriptive water savings for each efficiency level are presented below:

Efficiency Level	Efficient Products & RNC ?Water (CCF per year)			Multifamily New Construction ΔWater (CCF per year)		
	Front Loading	Top Loading	Weighted Average	Front Loading	Top Loading	Weighted Average
ENERGY STAR	2.4	0.7	1.1	2.1	0.7	1.0
CEE TIER 2	2.4	n/a	2.4	2.1	n/a	2.1
CEE ADVANCED TIER	2.7	n/a	2.7	2.4	n/a	2.4

Early Replacement:

The weighted average savings are provided below, based on weighting the first year savings for 3 years and the reduced savings for the remaining 11 years. Note the screening tool currently does not allow mid life adjustments to be applied to water savings.

Efficiency Level	Single Family Early Replacement ΔWater (CCF per year) Weighted Average for Screening Replacing:		Multifamily Early Replacement ΔWater (CCF per year) Weighted Average for Screening Replacing:	
	Front Loading	Top Loading	Front Loading	Top Loading
ENERGY STAR	5.0	3.6	4.2	3.0
CEE TIER 2	5.2	5.2	4.4	4.4
CEE ADVANCED TIER	5.6	5.5	4.6	4.6

Footnotes

[1] Assume one hour per cycle.

[2] The percentage of total energy consumption that is used for the machine, heating the hot water or by the dryer is different depending on the efficiency of the unit. Values are based on a weighted average of top loading and front loading units (based on available product from the CEC Appliance database), 8/18/2017 and consumption data from the latest Life-Cycle Cost and Payback Period Excel-based analytical tool. See "2018 Clothes Washer Analysis.xls" for the calculation.

[3] Based on data received by Efficiency Vermont on 08/21/2017 from the upcoming NMR Vermont Residential Market Assessment.

[4] Based on the average clothes washer volume of all units that pass the new Federal Standard on the California Energy Commission (CEC) database of Clothes Washer products accessed on 08/18/2017**.**

[5] Weighted average of 322 clothes washer cycles per year. 2009 Residential Energy Consumption Survey (RECS) national sample survey of housing appliances section: http://www.eia.gov/consumption/residential/data/2009/

[6] EVT found the average household size in MF buildings from the 2010 Census data (1.6 people, compared to 2.3 for single family) and using the values for number of loads for different household sizes (from DOE Technical Support Document U.S. Department of Energy, Final Rule Technical Support Document (TSD): Energy Efficiency Standards for Consumer Products: Clothes Washers, December, 2000. Page 7-6) and the 322 used for single families we estimate the number of loads for a MF building to be 265. See '2018 Clothes Washer Analysis.xls' for calculation.

[7] To account for the different efficiency of electric and Natural Gas hot water heaters (gas water heater: recovery efficiencies ranging from 0.74 to 0.85 (0.78 used), and electric water heater with 0.98 recovery efficiency). Therefore a factor of 0.98/0.78 (1.26) is applied.

[8] Based on DOE Life-Cycle Cost and Payback Period Excel-based analytical tool.

[9] Based on inflating cost data from Life-Cycle Cost and Payback Period Excel-based analytical tool,. See ‘2018 Clothes Washer Analysis.xls’ for details.

[10] Note that the baseline savings for all cases (Front, Top and Weighted Average) is based on the weighted average baseline IMEF (as opposed to assuming Front baseline for Front efficient unit). The reasoning is that the support of the program of more efficient units (which are predominately front loading) will result in some participants switching from planned purchase of a top loader to a front loader.

[11] Note for early replacement we are assuming the baseline unit configuration is always known but are using the weighted average IMEF for the efficient case for simplicity.

ENERGY STAR Clothes Dryer

Measure Number: IV-A-2 c
Portfolio: EVT TRM Portfolio 2017-03
Status: Active
Effective Date: 2017/1/1
End Date: [None]
Program: Efficient Products Program
End Use: Clothes Washing

Update Summary

- Addition of early replacement assumptions, algorithms, and measure codes

Applicable Markets

Applicable Markets
Efficient Products
Residential New Construction
Multifamily In Unit New Construction
Multifamily In Unit Retrofit
Low Income Single Family Retrofit
Existing Homes Retrofit

Referenced Documents

- 2011-04-18_TSD_Chapter_8_Life-Cycle_Cost_and_Payback_Period_Analyses
- 2014 Emerging Technology Award _Advanced Clothes Dryer Models
- 2014 ENERGY STAR Emerging Technology Advanced Clothes Dryers Criteria
- ENERGY STAR Draft 2 Version 1
- ENERGY STAR Final Version 1 0 Clothes Dryers Program Requirements
- Appendix J2 To Subpart B Of Part 430—Uniform Test Method For Measuring The Energy Consumption Of automatic And Semi-Automatic Clothes Washers
- ENERGY STAR Dryer Specification NEEA Amended comments Mar 26 2013
- 2016 Clothes Dryer Analysis
- HPWH_TRM_Analysis_2015.xlsx
- 2014 Emerging Technology Award _Advanced Clothes Dryer Models_Update Dryer QPL 3 25 2016
- Blomberg_EPA PARTNER MEETING - SEDI SESSION 10142015
- VT SF Existing Homes Onsite Report_final 021513
- ER Clothes Dryer Analysis

Description

Clothes dryers exceeding minimum qualifying efficiency standards established as ENERGY STAR or 2014 Emerging Technology Award (both hybrid and full heat pump models), based on Combined Energy Factor (CEF), as described below under High Efficiency.

The CEF measures energy consumption of the total dryer cycle (standby usage, dryer heating and operation) in units of weight (lbs) of clothing dried per kWh of electricity; the higher the number, the greater the efficiency. In the case of gas dryers, the CEF combines both the gas and electric usage into a single CEF metric also measured in units of weight of clothing dried per kWh of electricity.

Baseline Efficiencies

Market Opportunity:

The baseline combined energy factor (CEF) was derived in the ENERGY STAR Version 1.0 analysis by multiplying 2015 federal standards by the average change in a dryers' assessed CEF between the required (Appendix D1) and optional (Appendix D2) test procedure required by the ENERGY STAR eligibility requirements. This gives 3.11 CEF for electric dryers and 2.84 for gas dryers.

Early Replacement:

The baseline in this case is the efficiency of the existing unit for its assumed remaining life (4 years) and the new baseline as defined above for the remainder of the measure (remaining 8 years). The Federal baseline for clothes dryers prior to 2015 had been in place since 1994. The standard was 3.01 EF for electric units and 2.67 EF for gas. Comparing new units Combined Energy Factor (which include accounting for standby loads in addition to active drying energy) with older units Energy Factor (which only accounts for active drying energy) is challenging and complicated further by significant changes in testing procedures over the years. However, there hasn't been significant change in actual clothes dryer performance over the past decades and using these EF without any adjustment is consistent with this and so is used as an estimate of existing unit efficiency.

Efficient Equipment

High efficiency is defined as any model meeting or exceeding ENERGY STAR or 2014 Emerging Technology Award criteria, as defined in the following table:

Efficiency Level	**Combined Energy Factor (CEF)** **Lbs / kWh**
ENERGY STAR (Electric)	>= 3.93 in "Normal" setting
ENERGY STAR (Gas)	>= 3.48 in "Normal" setting
2014 Emerging Technology Award (Electric)[1]	>= 4.3 in "Normal" setting >= 5.3 in "Most Efficient" setting

Energy savings estimates are based on the resulting product from multiplying the average CEF of ENERGY STAR certified dryers on 4/22/2016 and the average load weight associated with the paired washer model capacities. The average capacity of ENERGY STAR certified dryers is used to look up the corresponding average load size in the U.S. DOE clothes washer test procedure (10 CFR 430, Subpart B, Appendix J2 Table 5.1). An additional waste heat calculation has been incorporated in to the final savings determination. This accounts for the unit's waste heat either being predominately vented to outside or remaining in the home and reducing the heating demands (notably in ventless hybrid and full heat pump models).

Algorithms

Electric Demand Savings

ΔkW $= \Delta kWh/Hours$

Symbol Table

Electric Energy Savings

Market Opportunity: ΔkWh_{unit} $= Weight \times (1/CEF_{base} - 1/CEF_{eff}) \times \%Elec \times \%Washer \times N_{cycles}$

Early Replacement: ΔkWh_{unit} $= Weight \times (1/CEF_{exist} - 1/CEF_{eff}) \times \%Elec \times \%Washer \times N_{cycles}$

$\Delta kWh_{WasteHeat}$ $= \Delta kWh_{Heat} + \Delta kWh_{Cool}$

$\Delta kWh_{Heat} = kWh_{HeatBase} - kWh_{HeatEff}$

$kWh_{Heat} = (\%HeatSpace \times WHHF \times \%HeatSource \times \%Conditioned \times Dryer\ Consumption)/COPHeat$

$\Delta kWh_{Cool} = kWh_{CoolBase} - kWh_{CoolEff}$

$kWh_{Cool} = (\%HeatSpace \times WHCF \times \%Cooling \times \%Conditioned \times Dryer\ Consumption)/COPCool$

ΔkWh $= \Delta kWhUnit + kWhVentless + \Delta kWhWasteHeat$

Resulting savings for Market Opportunity[15]:

Efficiency Level	**CEF** **(lbs/kWh)**	**Load Weight** **(lbs)**	**% Energy Reduction from Paired Efficient Washers**	**HVAC Impact from Ventless Dryers (kWh)**	**Waste Heat Impact (kWh)**	**ΔkWh WasteHeat**	**Annual Dryer Savings (kWh)**	**kW Savings (kW)**
ENERGY STAR Version 1.0 Estimated Baseline (Electric)	3.11	10.4	N/A	N/A	0.1		N/A	N/A
ENERGY STAR Version 1.0 Estimated Baseline (Gas)	2.84		N/A		0.1		N/A	N/A
ENERGY STAR (Standard Electric)	3.93		14%		0.1	0.0	194	0.60
ENERGY STAR (Standard Gas)	3.49		14%		0.1	0.0	36	0.11
2014 Emerging Technology Award Vented (Electric)	4.35 / 5.6		16%		0.0	0.0	366	1.14
2014 Emerging Technology Award Ventless (Electric)	5.27 / 6.36		13%	3	0.9	0.8	457	1.42
2014 Emerging Technology Award Ventless Full Heat Pump (Electric)	10.4		13%	3	0.5	0.4	658	2.04

Savings for Early Replacement (first 4 years)[16]:

			% Energy	**HVAC Impact**	**Waste**		**Annual**	**kW**

Efficiency Level	CEF (lbs/kWh)	Weight (lbs)	from Paired Efficient Washers	from Ventless Dryers (kWh)	Heat Impact (kWh)	ΔkWh WasteHeat	Dryer Savings (kWh)	Savings (kW)
Existing Unit (Electric)	3.01	10.4	N/A	N/A	0.10	0.00	N/A	N/A
Existing Unit (Gas)	2.67		N/A		0.11	0.00	N/A	N/A
ENERGY STAR (Standard Electric)	3.93		0.13		0.07	-0.03	226.02	0.70
ENERGY STAR (Standard Gas)	3.49		0.13		0.08	-0.04	48.42	0.15
2014 Emerging Technology Award Vented (Electric)	4.35 / 5.6		0.16		0.05	-0.05	398.42	1.24
2014 Emerging Technology Award Ventless (Electric)	5.27 / 6.36		0.13	3.00	0.87	0.77	489.55	1.52
2014 Emerging Technology Award Ventless Full Heat Pump (Electric)	10.40		0.13	3.00	0.50	0.40	690.67	2.14

Symbol Table

Fossil Fuel Savings

Market Opportunity: ΔMMBtuUnit	= Weight × (1/CEF_{base} – 1/CEF_{eff}) × (1-%Elec) × %Washer × N_{cycles} × MMBtu_convert × % Fuel_Dryer
Early Replacement (1st 4 years): $\Delta MMBtu_{unit}$	= Weight × (1/CEF_{exist} – 1/CEF_{eff}) × (1-%Elec) × %Washer × N_{cycles} × MMBtu_convert × % Fuel_Dryer
$\Delta MMBtu_{WasteHeat}$	= $MMBtu_{WasteHeatBase}$ - $MMBtu_{WasteHeatEff}$ $MMBtu_{WasteHeat}$ = (%HeatSpace × WHHF × %HeatSource × %Conditioned × Dryer Consumption × 0.003412)/ ηHeat
ΔMMBtu	= ΔMMBtuUnit + ΔMMBtuVentless + ΔMMBtuWasteHeat

Fossil Savings for Market Opportunity:

	Total MMBtu	NG	LP	Oil	Wood
ENERGY STAR (Electric)	-0.02	-0.01	0.00	-0.01	0.00
ENERGY STAR (Gas)	0.50	0.16	0.35	-0.01	0.00
2014 Emerging Technology Award Vented Hybrid (Electric)	-0.05	-0.01	-0.01	-0.02	-0.01
2014 Emerging Technology Award Ventless Hybrid (Electric)	1.11	0.19	0.15	0.53	0.24
2014 Emerging Technology Award Ventless Full Heat Pump (Electric)	0.77	0.12	0.10	0.36	0.19

Fossil Savings for Early Replacement (1st 4 years):

	Total MMBtu	NG	LP	Oil	Wood
ENERGY STAR (Electric)	-0.02	-0.01	0.00	-0.01	0.00
ENERGY STAR (Gas)	0.68	0.21	0.48	-0.01	0.00
2014 Emerging Technology Award Vented Hybrid (Electric)	-0.05	-0.01	-0.01	-0.02	-0.01
2014 Emerging Technology Award Ventless Hybrid (Electric)	1.11	0.19	0.15	0.53	0.24
2014 Emerging Technology Award Ventless Full Heat Pump (Electric)	0.77	0.12	0.10	0.36	0.19

Where:

% Fuel_Dryer = Percentage of dryer savings by fuel type[4]

Dryer fuel	% Fuel_Dryer
Natural Gas	31%
LP Gas	69%

%Conditioned = Portion of homes with dryer in conditioned space

= 73%[3]

%Cooling = Percent of homes with central cooling

= 2%[4]

%Elec = Percentage of electric to total energy for dryer operation

= Values provided in table below

	Percentage of Total Energy Consumption[5]	
	%Elec (Electric)	**%Heat (Gas)**
ENERGY STAR (Standard Electric)	100%	0%
ENERGY STAR (Standard Gas)	19%	81%

%HeatSource = Portion of homes with fuel source[6]:

Fuel Source	Portion of homes (%HeatSource)
Natural Gas	21%
Propane gas	15%
Fuel Oil	51%
Wood	12%

%HeatSpace = Proportion of dryer heat energy remaining in space:

Unit Type	**%HeatSpace**
Vented	5%
Ventless	100%

%Washer = Reduction in dryer savings from efficient clothes washers[7]

= Values provided in table below

Efficiency Level	**% Energy Reduction from Paired Efficient Washers**
ENERGY STAR (Standard Electric)	14%
ENERGY STAR (Standard Gas)	14%
2014 Emerging Technology Award Vented Hybrid Heat Pump (Electric)	16%
2014 Emerging Technology Award Ventless Hybrid Heat Pump (Electric)	14%
2014 Emerging Technology Award Ventless Full Heat Pump (Electric)	14%

ΔkWh = Total gross customer annual kWh savings for the measure

ΔkW = Gross customer connected load kW savings for the measure

ΔkWh_{Cool} = Impact of waste heat on cooling loads

ΔkWh_{Heat} = Impact of waste heat on heating loads

ΔkWh_{unit} = Gross electric savings for operation of clothes dryer

$\Delta kWh_{WasteHeat}$ = Gross electric savings relating to waste heat impacts

ΔkWh = Total gross customer annual kWh savings for the measure

$\Delta MMBtu_{WasteHeat}$ = Heating impact associated with waste heat of unit

$\Delta MMBtu$ = Total gross fuel savings for the measure

ΔMMBtuUnit = Gross fuel savings for operation of clothes dryer

ΔMMBtuVentless = HVAC In-direct fossil fuel savings from ventless dryer, by fuel type[17]

Values provided in table below for ETA Ventless dryers; zero for all others

	Total MMBtu	NG	LP	Oil	Wood

2014 Emerging Technology Award Ventless (Electric)	0.39	0.05	0.05	0.17	0.13

ΔMMBtuWasteHeat = Gross fuel savings relating to waste heat impacts

ηHeat = Efficiency of heating system[18]:

Fuel Source	Heating efficiency (ηHeat)
Natural Gas	87.8%
Propane gas	87.4%
Fuel Oil	84.2%
Wood	65%

ΔkWhUnit = Gross electric savings from operation of the clothes dryer

CEF_{base} = Combined Energy Factor of baseline unit based on full cycle testing of conventional dryers[8]

Values provided in table below

CEF_{eff} = Combined Energy Factor of efficient unit

Values provided in table below

CEF_{exist} = Combined Energy Factor of existing unit[9]

Values provided in table below

COPCool = Coefficient of Performance of cooling system

= 3.0[10]

COPHeat = Coefficient of Performance of heating system

= 1.5[11]

Dryer Consumption = See Tables

Hours = Assumed annual run hours of clothes dryer

= Ncycles * 1 Hour

= 322[2]

$kWh_{CoolBase}$ = Waste heat impacts on cooling for baseline unit

$kWh_{CoolEff}$ = Waste heat impacts on cooling for efficient unit

$kWh_{HeatBase}$ = Waste heat impacts on heating for baseline unit

$kWh_{HeatEff}$ = Waste heat impacts on heating for efficient unit

$kWh_{Ventless}$ = HVAC In-direct electric savings from ventless dryer not having to reheat make-up air[4870]

= 3 kWh for ETA ventless dryer and Heat Pump; 0 kWh for all others

$MMBtu_{WasteHeatBase}$ = Waste heat impacts on heating for baseline unit

$MMBtu_{WasteHeatEff}$ = Waste heat impacts on heating for efficient unit

MMBtu_convert = Conversion factor from kWh to MMBtu

=0.003413

N_{cycles} = Number of Cycles per year

=322[12]

Weight = Average clothes dryer load weight (lbs) based on DOE average test load size of paired washer.

=10.4 lbs[13]

WHCF = Portion of waste heat that results in increased cooling

= 0.188[14]

WHHF = Portion of reduced waste heat that results in increased heating

= 0.558[19]

Mid Life Savings Adjustment

The follow mid life savings adjustments are applied to the annual savings for early replacement measures after 4 years:

Efficiency Level	Electric Adjustment	Fossil Adjustment
ENERGY STAR (Standard Electric)	86%	91%
ENERGY STAR (Standard Gas)	74%	73%
2014 Emerging Technology Award Vented (Electric)	92%	94%
2014 Emerging Technology Award Ventless (Electric)	93%	100%
2014 Emerging Technology Award Ventless Full Heat Pump (Electric)	95%	100%

Load Shapes

9a Residential Clothes Washer

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
9	Residential Clothes Washer	Active	42.0 %	28.8 %	16.9 %	12.3 %	4.4 %	3.3 %

Net Savings Factors

Measures

CKLESDRY	Efficient Clothes Dryer
CKLESETA	2014 Emerging Technology Award
CKLERESD	Early Replacement ENERGY STAR Clothes Dryer
CKLERETD	Early Replacement Emerging Technology Award Clothes Dryer

Tracks [Base Track]

6032EPEP [is base track]	Efficient Products - Residential
6034LISF [is base track]	LISF Retrofit
6036RETR [is base track]	Res Retrofit
6036HPES [6036RETR]	HPwES EVT

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Efficient Products - Residential	6032EPEP	CKLESDRY	0.90	1.10
Efficient Products - Residential	6032EPEP	CKLESETA	1.00	1.20
LISF Retrofit	6034LISF	CKLESDRY	1.00	1.00
LISF Retrofit	6034LISF	CKLESETA	1.00	1.00
Res Retrofit	6036RETR	CKLESDRY	0.90	1.00
Res Retrofit	6036RETR	CKLESETA	0.90	1.00
Efficient Products - Residential	6032EPEP	CKLERESD	1.00	1.00
LISF Retrofit	6034LISF	CKLERESD	1.00	1.00
Res Retrofit	6036RETR	CKLERESD	1.00	1.00
Efficient Products - Residential	6032EPEP	CKLERETD	1.00	1.00
LISF Retrofit	6034LISF	CKLERETD	1.00	1.00
Res Retrofit	6036RETR	CKLERETD	1.00	1.00

Lifetimes

12 years[20]

Analysis period is the same as the lifetime.

For early replacement the existing unit is assumed to have a remaining life of 4 years (1/3 of the measure life).

Measure Cost

The incremental cost and full install cost for this measure is provided in the table below[21]:

Efficiency Level	Market Opportunity Incremental Cost	Early Replacement

		Full Install Cost
ENERGY STAR	$61	$528
2014 Emerging Technology Award	$412	$879

For early replacement measures, the deferred baseline replacement cost that would have been incurred after 4 years had the existing unit not been replaced is assumed to be $467.

O&M Cost Adjustments

There are no operation and maintenance cost adjustments for this measure.

Footnotes

[1] Although the 2014 Emerging Technology Award criteria are the basis for program eligibility, the actual performance measurements from the 11/3/2014 list of 2014 Emerging Technology Award Winning Dryers are used for characterizing the measure savings for the ventless Whirlpool and the vented LG award winning dryer models. The performance specification is anticipated to change later in 2015 based on new ENERGY STAR Most Efficient and/or CEE tiered specifications. Eligibility for the current award criteria is anticipated to end on December 31st, 2014.

[2] Weighted average of 322 clothes washer cycles per year based on the Efficiency Vermont 2014 Technical Resource Manual clothes washer measure characterization. Federal standard employs a 0.91 field use factor, based on RECS 2009 survey data suggesting not all clothes washer loads are dried, but in earlier proceedings DOE references a higher percentage (0.96) for households with a dryer. A field evaluation completed by NEEA in 50 homes in the Northwest found a higher number of annual dryer cycles (337) than currently represented in the RECS data, noting users may not have consolidated their loads to the extent EPA assumed and were doing a significant percentage of "touch up" loads. Approximately one hour per cycle based on the ENERGY STAR clothes dryer qualified product list as of 9/15/2014. http://www.energystar.gov/sites/default/files/specs//ENERGY%20STAR%20Dryer%20Specification%20NEEA%20Amended%20comments%20Mar%2026%202013.pdf. Page 7.

[3] NEEP Study found 16 of 22 sites had the dryer in a heated space; NEEP, Energy & Resource Solutions "Electric Dryer Baseline Research", p8.

http://www.neep.org/sites/default/files/Microsoft%20PowerPoint%20-%20NEEP%20Dryer%20Presentation%20Final%2003-30-15.pdf

[4] Based on 'Vermont Single-Family Existing Homes Onsite Report', 2/15/2013, p67.

[5] The percentage of individual energy consumption used by the machine (%Elec) and separately for heating (%Heat) the dryer drum was derived from the ENERGY STAR Version 1.0 analysis; see 2016 Clothes Dryer Analysis.xlsx

[6] Split of primary heating fuels from the VT SF Existing Homes Onsite Report Table 5-1 after removing homes with natural gas space heat. (NMR Group, Inc. 2013).

[7] The percentage of energy reduction reflects the amount of dryer energy already captured by the performance of efficient clothes washers. The effective performance of paired clothes washers for both the ENERGY STAR and 2014 ETA dryers reflect the market share and relative remaining moisture content for clothes washers both in-program (rebated) and out-of-program (non-rebated). See 2014 Clothes Dryer Analysis with HVAC Impact.xlsx.

[8] The Combined Energy Factor (CEF) includes standby usage, dryer heating and operation electric use: *"The clothes dryer test load weight in pounds divided by the sum of the per cycle standby and off mode energy consumption and either the total per-cycle electric dryer energy consumption or the total per-cycle gas dryer energy consumption expressed in kilowatt hours (kWh)."* Definition provided in the ENERGY STAR® Program Requirements Product Specification for Clothes Dryers Eligibility Criteria Version 1.0

[9] Base on the federal baseline for clothes dryers prior to 2015, which had been in place since 1994. The standard was 3.01 EF for electric units and 2.67 EF for gas.

[10] Average efficiency of AC system is 11.6 SEER (based on 'Vermont Single Family Existing Homes Onsite Report', 2013, p65).
Convert to EER: (-0.02 * SEER2) + (1.12 * SEER) = 10.3 EER (calculation from Wassmer, M. (2003). A Component-Based Model for Residential Air Conditioner and Heat Pump Energy Calculations. Masters Thesis, University of Colorado at Boulder).
Convert to COP: EER/3.412 = 3.02 COP

[11] The COP used here is an assumption based upon a 50/50 split between resistance COP 1.0 and average Heat Pump effective COP of 2.0.

[12] [1] Weighted average of 322 clothes washer cycles per year based on the Efficiency Vermont 2014 Technical Resource Manual clothes washer measure characterization. A field evaluation completed by NEEA in 50 homes in the Northwest found a higher number of annual dryer cycles (337) than currently represented in the RECS data. Federal standard employs a 0.91 field use factor, based on RECS 2009 survey data suggesting not all clothes washer loads are dried. However, NEEA found a higher number of dryer loads, noting users may not have consolidated their loads to the extent EPA assumed. http://www.energystar.gov/sites/default/files/specs//ENERGY%20STAR%20Dryer%20Specification%20NEEA%20Amended%20comments%20Mar%2026%202013.pdf. Page 7.

[13] Based on average of ENERGY STAR qualified dryers on 9/15/2014 and available paired washer model capacity. This average capacity is then used to look up the average load size in the U.S. DOE clothes washer test procedure (10 CFR 430, Subpart B, Appendix J2 Table 5.1), see 2014 Clothes Dryer Analysis with HVAC Impact.xlsx

[14] Based on bin analysis of annual cooling hours for Burlington, VT using TMY3 data: 1650/8760 = 18.8%, see "2016 Clothes Dryer Analysis.xlsx"

[15] See "2016 Clothes Dryer Analysis.xlsx" for calculation.

[16] See "ER Clothes Dryer Analysis.xlsx" for calculation.

[17] HVAC In-direct savings for ventless dryers are based on the penetration of cooling systems, heating fuel types and corresponding efficiencies identified in the 'Vermont Single-

Family Existing Homes Onsite Report', 2/15/2013, see HVAC Inputs tab in 2014 Clothes Dryer Analysis with HVAC Impact.xlsx.

[18] Weighted efficiencies based on VT SF Existing Homes Onsite Report Table 5-8 and 5-9. (NMR Group, Inc. 2013). Efficiency for homes using wood or pellet stoves based on review of EPA-Certified wood stoves (U.S. Environmental Protection Agency n.d.)

[19] Based on bin analysis of annual heating hours for Burlington, VT using TMY3 data: 4885 / 8760 = 55.8%, see "2016 Clothes Dryer Analysis.xlsx

[20] Based on average lifetime in DOE Buildings Data Book http://buildingsdatabook.eren.doe.gov/TableView.aspx?table=5.7.15

[21] See 2014 Clothes Dryer Analysis with HVAC Impact.xlsx. Based on DOE Life-Cycle Cost and Payback Period analysis Table 8.3.1, http://www.regulations.gov/contentStreamer?objectId=0900006480c8ee12&disposition=attachment&contentType=pdf

Ultra Efficient LCD Monitors

Measure Number: IV-G-2 b
Portfolio: 89
Status: Active
Effective Date: 2016/1/1
End Date: [None]
Program: Efficient Products Program
End Use: Electronic Technology

Update Summary

Update to ENERGY STAR Version 6 specifications.

Referenced Documents

- ENERGY STAR V6 LCD Analysis_2015_FINAL
- ECOVA_Displays Program Potential Energy Savings Analysis 8-14-14
- Michigan Electric and Natural Gas Energy Efficiency Potential Study, 2013

Description

With rapid advancements in LCD (Liquid Crystal Display) technology, LCD monitors are quickly replacing older CRT technologies in both residential and commercial applications. This program will provide an incentive with the purchase of a LCD monitor that meets or exceeds the Energy Star Version 6.0 specification by 10%, 15%, 20%, 30%, or 40% in place of one of a monitor meeting and not exceeding Energy Star Version 6.0. The monitors will be broken out into bin sizes because larger size screens consume larger amounts of energy.

Estimated Measure Impacts

Algorithms

Electric Demand Savings

Demand savings are a weighted representation of monitors sales based on retail partners and manufacturer data reported to Ecova. This algorithm is identical for Residential and Commercial applications. Additionally, the savings are based on active mode values for both the baseline and energy efficient monitors[1].

$$\Delta kW_{LCD\ Monitor} = WattsBASE - WattsEE / 1000$$

Symbol Table

Electric Energy Savings

Average Energy Savings over all hours based on efficiency savings during active, standby and idle operational modes.[697]

$$\Delta kWh = (W_{BaseActive} - W_{ESActive}) / 1000 \times HOURS_{Active}$$

Where:

ΔkW = gross customer connected load kW savings for the measure

ΔkWh = gross customer annual kWh savings for the measure

$HOURS_{Active}$ = average active hours of use of the monitor per year

Sector	Active (hr/yr)	Sleep (hr/yr)	Off (hr/yr)
Commercial[2]	2,474	4,093	2,193
Residential[3]	1,533	4,453	2,811

$W_{BaseActive}$ = power use (in Watts) of baseline monitor while in on mode (i.e. active mode turned on and operating)

$W_{ESActive}$ = power use (in Watts) of efficient monitor in active mode (i.e. active mode turned on and operating)

WattsBASE = Baseline connected Watts as a weighted average of Energy Star 6.0 LCD monitors

WattsEE = connected watts of high efficiency LCD monitors exceeding Energy Star 6.0 specifications

The following ΔkW and ΔkWh are per monitor.

Commercial (ΔkW)	Efficiency Level			
	ESv6 + 10%	ESv6 + 15%	ESv6 + 20%	ESv6 + 30%
17≤d<23	0.004	0.005	0.006	0.008
23≤d<25	0.006	0.006	0.006	0.009
25≤d<61	0.009	0.009	0.009	0.018

Residential (ΔkW)	Efficiency Level		
	ESv6 + 10%	ESv6 + 15%	ESv6 + 20%
17≤d<23	0.004	0.004	0.004
23≤d<25	0.004	0.006	0.006
25≤d<61	0.005	0.006	0.008

Commercial (ΔkWh)	ESv6 + 10%	ESv6 + 15%	ESv6 + 20%	ESv6 + 30%
17≤d<23	7.4	10.6	10.4	15.7
23≤d<25	14.3	14.5	14.8	21.7
25≤d<61	21.4	21.4	21.4	45.6

Residential (ΔkWh)	ESv6 + 10%	ESv6 + 15%	ESv6 + 20%
17≤d<23	7.3	7.6	6.9
23≤d<25	7.2	9.7	9.9
25≤d<61	8.4	10.9	13.7

Baseline Efficiencies

Baseline is a monitor meeting the minimum and not exceeding the Energy Star 6.0 criteria.

High Efficiency

High efficiency is an LCD Monitor exceeding the Energy Star 6.0 requirements by 10%, 15%, 20%, or 30%.[4]

Operating Hours

Operating hours vary according to usage patterns for both residential and commercial LCD monitors.

Load Shapes

Assumed load profile from 80 Plus computer program < *Internal Power Supply Load Profile.x*ls>

Freeridership factor from *Work Paper: High Efficiency LCD Computer Monitor Program For the Mass Market Channel, p. 3*

74a Internal Power Supply, Commercial Desktop
75a Internal Power Supply, Residential Desktop

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
74	Internal Power Supply, Commercial Desktop	Active	39.2 %	27.5 %	19.6 %	13.7 %	50.0 %	80.0 %
75	Internal Power Supply, Residential Desktop	Active	33.8 %	32.9 %	16.9 %	16.4 %	52.2 %	40.5 %

Net Savings Factors

Net to Gross values below.[5]

Measures

EQPMONTR Efficient Computer Monitor

Tracks [Base Track]

6032EPEP [is base track] Efficient Products - Residential

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Efficient Products - Residential	6032EPEP	EQPMONTR	0.70	1.00

Persistence

The persistence factor is assumed to be one.

Lifetimes

Measure life is based on an estimated monitor life of 4 years. [6]

Measure Cost

The incremental cost for the Ultra Efficient LCD Monitor is $2.60[7]

O&M Cost Adjustments

$0

Fossil Fuel Description

Reference Tables

Energy Star 6.0 Display Maximum On Mode Power Table, P_{ON_MAX}

Screen Size	Displays with Dp ≤20,000 pixels/in^2	Displays with Dp > 20,000 pixels/in^2
Computer Monitors, Signage Displays, and Digital Picture Frames		
d<12.0	(6.0xr)+(0.05xA)+3.0	(6.0xr1)+(3.0xr2)+(0.05xA)+3.0
12.0≤d<17.0	(6.0xr)+(0.01xA)+5.5	(6.0xr1)+(3.0xr2)+(0.01xA)+5.5
17.0≤d<23.0	(6.0xr)+(0.025xA)+3.7	(6.0xr1)+(3.0xr2)+(0.025xA)+3.7
23.0≤d<25.0	(6.0xr)+(0.06xA)-4.0	(6.0xr1)+(3.0xr2)+(0.06xA)-4.0
25.0≤d ≤61.0	(6.0xr)+(0.1xA)-14.5	(6.0xr1)+(3.0xr2)+(0.1xA)-14.5
Signage Displays 30 Inches and Over		
30.0≤d≤61.0	(0.27xA)+8.0	(0.27xA)+8.0

Ultra Efficient LCD Monitor Power Requirements Table

Category	Energy Star 6.0
Standby (Off Mode)	≤ .5 W
Sleep Mode	≤ .5 W
Active State	
< 27 inches	0.30*P_{ON_MAX}
≥ 27 inches	0.75*P_{ON_MAX}

Incentive Level

Footnotes

[1] Ecova, Displays Program Potential Energy Savings Analysis, 2014. ECOVA_Displays Program Potential Energy Savings Analysis 8-14-14.docx

[2] Page 137, Table 5-20. Navigant Consulting, Inc. (2009). *Energy Savings Potential and RD&D Opportunities for Commercial Building Appliances.* Prepared for U.S. Department of Energy, Energy Efficiency and Renewable Energy Building Technologies Program.

[3] Page 55, Table 3-34. Urban, Bryan, Verena Tiefenbeck, and Kurt Roth (2014). *Energy Consumption of Consumer Electronics in U.S. Homes in 2013*. Prepared for the Consumer Electronics Association by Fraunhofer Center for Sustainable Energy Systems.

[4] *ENERGY STAR Program Requirements for Displays (Version 6.0)*

[5] *Work Paper: High Efficiency LCD Computer Monitor Program For the Mass Market Channel, p. 3*

[6] Michigan Electric and Natural Gas Energy Efficiency Potential Study, 2013, Page 298: http://www.dleg.state.mi.us/mpsc/electric/workgroups/mi_ee_potential_studyw_appendices.pdf

[7] Page 52, Electronic Displays, Codes and Standards Enhancement (CASE) Initiative for PY 2013: Title 20 Standards Development. March 8, 2013.

Efficient Televisions

Measure Number:	IV-G-3 c
Portfolio:	92
Status:	Active
Effective Date:	2016/1/1
End Date:	[None]
Program:	Efficient Products Program
End Use:	Electronic Technology

Update Summary

- Updated Efficient Television citeria to new ENERGY STAR 7.0 version;
- Reformatted measure to new product criteria and Algorithms

Referenced Documents

- Fraunhofer 2014 Energy-Consumption-of-Consumer-Electronics
- Final_ENERGY_STAR_Most_Efficient_2015_Recognition_Criteria_Televisions
- FINAL Version 7.0 Television Program Requirements
- Copy of UHD TV Savings Analysis_WHEC Changes
- Consumer_Electronics_Calculator
- CEE_Electronics_Center_2015_TV_Report_Q2_Final
- 2016_ENERGY_STAR_Certified_Televisions_Analysis

Description

This program is designed to provide a midstream incentive to retailers to stock, promote, and sell televisions which meet or exceed ENERGY STAR Version 7.0[1]. The ES 7.0 Televisions that are incentivized under this program include the 4K UHD: ENERGY STAR v7.0 TV with 15% Extra Power Allowance[2], 4K UHD: ENERGY STAR v7.0 TV with 35% Extra Power Allowance, 4K UHD: ENERGY STAR v7.0 TV with 50% Extra Power Allowance, Non-4K UHD: ENERGY STAR v7.0 TV with 15% Less Power, Non-4K UHD: ENERGY STAR Most Efficient 2016 TV, and Non-4K UHD: ENERGY STAR Most Efficient 2016 TV with 20% Less Power.

Estimated Measure Impacts

Algorithms

Electric Demand Savings

ΔkW	$= (Watts_{BASE} - Watts_{EE}) / 1000$

Symbol Table

Electric Energy Savings

ΔkWh	$= (Watts_{BASE} - Watts_{EE}) / 1000 \times HOURS_{Active} \times 365$

Where:

ΔkW	=	gross customer connected load kW savings (active) for the measure
ΔkWh	=	gross customer annual kWh savings in Active Mode
$HOURS_{Active}$	=	average hours of use per year in Active Mode = 5.2[3]
$Watts_{BASE}$	=	Baseline connected Watts (active)
$Watts_{EE}$	=	Energy efficient connected Watts (active)

Baseline Efficiencies

Baseline[4] is a conventional television installation, based on ENERGY STAR Consumer Electronics Calculator’s Television Calculations. The 4K UHD baseline is based on max power Energy Star Version 7.0 with 75% UHD allowance[5].

High Efficiency

The High Efficiency Television[6] is based on an average for all products meeting ENERGY STAR 7.0. Specification. The models analyzed here include the 4K UHD: ENERGY STAR v7.0 TV with 15% Extra Power Allowance[7], 4K UHD: ENERGY STAR v7.0 TV with 35% Extra Power Allowance, 4K UHD: ENERGY STAR v7.0 TV with 50% Extra Power Allowance, Non-4K UHD: ENERGY STAR v7.0 TV with 15% Less Power, Non-4K UHD: ENERGY STAR Most Efficient 2016 TV, and Non-4K UHD: ENERGY STAR Most Efficient 2016 TV with 20% Less Power. The market for televisions is evolving fast, and Efficiency Vermont will revisit its program requirements annually as new efficient specifications and technologies emerge.

Operating Hours

Active Mode: 1,898 hours / year.

Load Shapes

94a Efficient Television

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
94	Efficient Television	Active	48.0 %	19.0 %	24.0 %	9.0 %	22.0 %	17.0 %

Net Savings Factors

Measures

EQPTLVSN	Efficient Televisions

Tracks [Base Track]

6032EPEP [is base track]	Efficient Products - Residential

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Efficient Products - Residential	6032EPEP	EQPTLVSN	0.90	1.10

Persistence

The persistence factor is assumed to be one.

Lifetimes

Measure life is 6 years[8].

Measure Cost

$0[9]

Based on anecdotal information provided by manufacturers during development of the V3.0 TV specification, qualified TVs won't have any differential in price when compared to non-qualified TVs due to efficiency improvements alone. Rather, price differentials will occur due to additional features/functionality that as a side-benefit, may lead to efficiency improvements, e.g., LED backlighting, etc. Price differentials will also occur between technologies, e.g., a similarly sized LCD will likely cost more than a plasma, irrespective of which model is ENERGY STAR qualified. However, models that utilize the same screen technology and incorporate similar features should not differ in price if one is ENERGY STAR qualified and the other is non-qualified.

O&M Cost Adjustments

$0

Fossil Fuel Description

N/A

Reference Tables

ENERGY STAR Version 7.0 Television kWh Savings[10]

	40-49"	50-59"	60"+
ENERGY STAR v7.0 TV with 15% Less Power	38.7	49.1	48.0
ENERGY STAR Most Efficient 2016 TV	47.1	60.0	58.9

ENERGY STAR Most Efficient 2016 TV with 20% Less Power	61.0	78.6	80.4

ENERGY STAR Version 7.0 Television kW Savings

	40-49"	50-59"	60"+
ENERGY STAR v7.0 TV with 15% Less Power	0.020	0.026	0.025
ENERGY STAR Most Efficient 2016 TV	0.025	0.032	0.031
ENERGY STAR Most Efficient 2016 TV with 20% Less Power	0.032	0.041	0.042

4K UHD ENERGY STAR Version 7.0 Television kWh Savings[11]

	40-49"	50-59"	60"+
4K UHD ENERGY STAR v7.0 TV with 15% Extra Power Allowance	49.7	69.6	104.5
4K UHD ENERGY STAR v7.0 TV with 35% Extra Power Allowance	42.1	57.7	78.7
4K UHD ENERGY STAR v7.0 TV with 50% Extra Power Allowance	28.3	53.2	69.2

4K UHD ENERGY STAR Version 7.0 Television kW Savings

	40-49"	50-59"	60"+
4K UHD ENERGY STAR v7.0 TV with 15% Extra Power Allowance	0.024	0.037	0.055
4K UHD ENERGY STAR v7.0 TV with 35% Extra Power Allowance	0.022	0.030	0.041
4K UHD ENERGY STAR v7.0 TV with 50% Extra Power Allowance	0.015	0.028	0.036

Footnotes

[1] Requirements for ENERGY STAR 7.0 Televisions can be found in FINAL Version 7.0 Television Program Requirements.pdf.

[2] TVs with Native Vertical Resolution greater than or equal to 2160 lines are eligible for a high resolution On Mode Power Allowance. This means that they are able to use up to 50% more energy than non-high resolution TVs certifying to ENERGY STAR V7.0.

[3] Hours of use can be found on Page 93 of Energy Consumption of Consumer Electronics, Fraunhofer USA, 2014. http://www.ce.org/CorporateSite/media/environment/Energy-Consumption-of-Consumer-Electronics.pdf

[4] Conventional Television values can be found in Consumer_Electronics_Calculator.xlsx

[5] Basis for baseline can be found in visualization displayed in Copy of UHD TV Savings Analysis.xlsx.

[6] Savings Calculations for CEE_Electronics_Center_2015_TV_Report_Q2_Final.xlsx

[7] TVs with Native Vertical Resolution greater than or equal to 2160 lines are eligible for a high resolution On Mode Power Allowance. This means that they are able to use up to 50% more energy than non-high resolution TVs certifying to ENERGY STAR V7.0.

[8] ENERGY STAR Program Requirements for Televisions, Partner Commitments Versions 6.0, accessed June 2013, http://www.energystar.gov/products/specs/system/files/Final%20Version%206%200%20TV%20Program%20Requirements.pdf.

[9] Mehernaz Polad, ICF International. Email from Robin Clark (ICF International) on April 10, 2008. This incremental cost correspondence was verified by Ecova on a conference call on 9/25/2012.

[10] Non-4K UHD Televisions calculations can be found in the Excel Document: 2016_ENERGY_STAR_Certified_Televisions_Analysis.xls

[11] 4K UHD Calculations can be found in the Excel Document: Copy of UHD TV Savings Analysis.xlsx

Controlled Power Strip

Measure Number: **IV-G-4 c**
Portfolio: EVT TRM Portfolio 2018-03
Status: Active
Effective Date: 2018/1/1
End Date: [None]
Program: Efficient Products Program
End Use: Electronic Technology

Update Summary

Update to add assumptions for market opportunity and for free giveaways to customers who request power strips.

Referenced Documents

- Loadshape_smart_revB
- Lockeed Martin Energy Solutions nyserda_powerstrip_report
- NYSERDA_Advanced Power Strips
- Report_NEEP-APS-Deemed-Savings-Report-4-30-12
- CalPlug_Tier2_APS_Evaluation
- UVM Dorm APS Study
- Cadmus_Process Evaluation Report PPL Electric Program Year 5_Nov 2014
- Cadmus_EmPOWER_EY4 Res Retro Impact Report_FINAL_June 2014
- EVT_Controlled Power Strip Analysis_Feb 2018

Description

This measure describes savings associated with Tier I Advanced Power Strips. These multi-plug power strips have the ability to automatically disconnect specific connected loads depending upon the power draw of a control load, also plugged into the strip. Power is disconnected from the switched (controlled) outlets when the control load power draw is reduced below a certain adjustable threshold, thus turning off the appliances plugged into the switched outlets. By disconnecting, the standby load of the controlled devices, the overall load of a centralized group of equipment (i.e. entertainment centers and home office) can be reduced.

This measure applies to the following implementation methods:

- Direct installation of power strips in residential buildings or in college dorms
- Retail sales
- Free giveways to customers who request power strips

Algorithms

Electric Demand Savings

$\Delta kW_{DI\_Entertainment\ Center}$	$= \Delta kWh_{DI\_Entertainment\ Center} / Hours_{Residential}$
ΔkW_{DI_Office}	$= \Delta kWh_{DI\_Office} / Hours_{Residential}$
$\Delta kW_{DI\_College}$	$= \Delta kWh_{DI\_College} / Hours_{College}$
ΔkW_{MOP}	$= \Delta kWh_{MOP} / Hours_{Residential}$
$\Delta kW_{Free\ Giveaway}$	$= \Delta kWh_{Free\ Giveaway} / Hours_{Residential}$

Symbol Table

Electric Energy Savings

$\Delta kWh_{DI\_Entertainment\ Center}$	$= SaveElec_{Entertainment\ Center} \times ISR$
ΔkWh_{DI_Office}	$= SaveElec_{Office} \times ISR$
$\Delta kWh_{DI\_College}$	$= SaveElec_{College} \times ISR$
ΔkWh_{MOP}	$= ((SaveElec_{Entertainment\ Center} \times \%Entertainment\ Center) + (SaveElec_{Office} \times \%Office)) \times ISR$
$\Delta kWh_{Free\ Giveaway}$	$= ((SaveElec_{Entertainment\ Center} \times \%Entertainment\ Center) + (SaveElec_{Office} \times \%Office)) \times ISR$

Where:

%Entertainment Center = Relative penetration of use with home entertainment systems

= 59%[3]

%Office = Relative penetration of use in home offices

= 41%[3]

$\Delta kW_{DI\_College}$ = Gross customer connected load kW savings for direct installation of power strips in college dorms (kW)

See Reference Tables section for deemed savings values

$\Delta kW_{DI\_Entertainment\ Center}$ = Gross customer connected load kW savings for direct installation of power strips in entertainment centers in residential buildings (kW)

See Reference Tables section for deemed savings values

ΔkW_{DI_Office} = Gross customer connected load kW savings for direct installation of power strips in home offices (kW)

See Reference Tables section for deemed savings values

$\Delta kW_{Free\ Giveaway}$ = Gross customer connected load kW savings for free giveaways (kW)

See Reference Tables section for deemed savings values

ΔkW_{MOP} = Gross customer connected load kW savings for market opportunity (kW)

See Reference Tables section for deemed savings values

$\Delta kWh_{DI\_College}$ = Gross customer annual kWh savings for direct installation of power strips in college dorms (kWh)

See Reference Tables section for deemed savings values

$\Delta kWh_{DI\_Entertainment\ Center}$ = Gross customer annual kWh savings for direct installation of power strips in entertainment centers in residential buildings (kWh)

See Reference Tables section for deemed savings values

ΔkWh_{DI_Office} = Gross customer annual kWh savings for direct installation of power strips in entertainment centers in home offices (kWh)

See Reference Tables section for deemed savings values

$\Delta kWh_{Free\ Giveaway}$ = Gross customer annual kWh savings for free giveaways (kWh)

See Reference Tables section for deemed savings values

ΔkWh_{MOP} = Gross customer annual kWh savings for market opportunity (kWh)

See Reference Tables section for deemed savings values

$Hours_{College}$ = Average hours of use per year in a college in efficient (controlled off) mode

= 4,953[1]

$Hours_{Residential}$ = Average hours of use per year in a residential application in efficient (controlled off) mode

= 8,048[2]

ISR = In service rate, or the percentage of units rebated that are actually installed

= 100% for direct install and market opportunity and 63% for free giveaways[4]

$SaveElec_{College}$ = Annual electric energy savings (kWh) for college dorm use

= 54.8[5]

$SaveElec_{Entertainment\ Center}$ = Annual electric energy savings (kWh) for entertainment center use

= 75.1[6]

$SaveElec_{Office}$ = Annual electric energy savings (kWh)for office use

= 31.0[6]

Baseline Efficiencies

The assumed baseline is a standard power strip that does not control any of the connected loads.

High Efficiency

The efficient case is the use of an advanced power strip.

Load Shapes

See Loadshape_smart_revB.xls

96a Standby Losses - Entertainment Center
97a Standby Losses - Home Office

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
96	Standby Losses - Entertainment Center	Active	32.0 %	35.0 %	16.0 %	17.0 %	72.5 %	90.0 %
97	Standby Losses - Home Office	Active	29.0 %	38.0 %	14.0 %	19.0 %	25.0 %	76.3 %

Net Savings Factors

Measures

EQPPWRHO	Residential Office Controlled Power Strip
EQPPWREC	Residential Entertainment Controlled Power Strip
EQPPWCEC	College Entertainment Controlled Power Strip

Tracks [Base Track]

6032EPEP [is base track]	Efficient Products - Residential
6034LISF [is base track]	LISF Retrofit
6036RETR [is base track]	Res Retrofit

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Efficient Products - Residential	6032EPEP	EQPPWRHO	1.00	1.00
Efficient Products - Residential	6032EPEP	EQPPWREC	1.00	1.00
LISF Retrofit	6034LISF	EQPPWRHO	1.00	1.00
LISF Retrofit	6034LISF	EQPPWREC	1.00	1.00
Res Retrofit	6036RETR	EQPPWRHO	1.00	1.00
Res Retrofit	6036RETR	EQPPWREC	1.00	1.00
Efficient Products - Residential	6032EPEP	EQPPWCEC	1.00	1.00
LISF Retrofit	6034LISF	EQPPWCEC	1.00	1.00
Res Retrofit	6036RETR	EQPPWCEC	1.00	1.00

Persistence

The persistence factor is assumed to be 1.

Lifetimes

The expected lifetime of the measure is 5 years[7].

Measure Cost

The installation cost of the measure is $21.48[8]

Measure costs are presented below, depending on program type.

Program Type	Measure Cost
Direct Install	$23.75[9]
MOP	$21.48[8]
Free Giveaway	$13.75[10]

O&M Cost Adjustments

There are no operation and maintenance cost adjustments for this measure.

Fossil Fuel Description

There are no fossil-fuel algorithms or default values for this measure.

Reference Tables

Savings are presented below, depending on program type.[5]

Program Type	ΔkW	ΔkWh
Direct Install: Entertainment Center	0.00933	75.1
Direct Install: Office	0.00385	31.0
Direct Install: College Dorm	0.01106	54.8
MOP	0.00708	57.0
Free Giveaway	0.00446	35.9

Footnotes

[1] Refer to APS in Dorms tab of analysis document: EVT_Controlled Power Strip_Analysis_Feb 2018.xlsx. Annual hours for college applications are calculated assuming a 32 week school year and results in 4,953 hours a year.

[2] Derived from CalPlug Tier 2 APS Evaluation Study Retrieved from: http://embertec.com/assets/pdf/CalPlug_Tier2_APS_Evaluation.pdf. Advanced Power Strips are assumed to be plugged in at all times. Annual hours when the equipment is turned off are 7,340. The equipment is estimated to be in standby mode 1.94 hours/day or 708 hours/year. Savings are achieved during periods when equipment is off or in standby mode. Thus, the hours of operation used to determine demand savings are 7,340 + 708 = 8,048. No savings are achieved during the remaining 712 hours per year when equipment is in use.

[3] Relative weightings of home office and entertainment systems is based on Cadmus Group & Navigant, "EmPower Maryland Final Evaluation Report – Evaluation Year 4; Residential Retrofit Programs," June 23, 2014, p. 91.

[4] Advanced power strip ISR is average of ISRs from Cadmus, "Process Evaluation Report, PPL Electric EE&C Plan, Program Year Five," November 13, 2014, p. 147.

[5] Analysis of energy savings from VEIC study at the University of Vermont. APS in Dorms: A New Application for Savings?, Vermont Energy Investment Corporation, 2014. Refer to analysis on APS in Dorms tab on EVT_Controlled Power Strip_Analysis_Feb 2018.xlsx.

[6] Advanced Power Strips Deemed Savings Methodology, Northeast Energy Efficiency Partnerships (NEEP), January 2012. Refer to Report_NEEP-APS-Deemed-Savings-Report-4-30-12.pdf.

[7] 10-year estimate: Lockheed Martin, Inc., Energy Solutions, Advanced Power Strip Research Report Final Report, Prepared for the New York State Energy Research and Development Authority (NYSERDA), 2011. As persistence has not been studied for this measure, 5 years is being used as a conservative estimate.

[8] Average of 5-plug and 7-plug incremental cost differences between a power strip and an advanced power strip, NYSERDA Advanced Power Strips Report, Page 4.

[9] Full installation cost for direct install based on actual program cost of $13.75 for an advanced power strip and labor estimated at 1/2 hour at $20/hour.

[10] Cost of an advanced power strip for free giveaways from actual program data.

Desktop Computers

Measure Number:	IV-G-5 a
Portfolio:	89
Status:	Active
Effective Date:	2016/1/1
End Date:	[None]
Program:	Efficient Products Program
End Use:	Electronic Technology

Update Summary

Referenced Documents

- 80-plus-market-progress-evaluation-report-5
- California_IOUs_Standards_Proposal_Computers_UPDATED_2013-08-06_TN-71813
- Ecova Completed Desktop Analysis_WestHill_Revised
- Energy Star 6 Requirements
- SDGE_Network Desktop Comp Power Mgmt Software

Description

This measure includes desktop computers with Energy Star Version 6.0 rating, ES 6.0 +20%, ES 6.0 with 80 PLUS Gold PSUs, and ES 6.0 with 80 PLUS Platinum PSUs. These measures are characterized for residential and commercial applications.

Baseline Efficiencies

The baseline measure is a desktop with no Energy Star rating.

Measure Watt Draw in Mode (Watts)	Off	Sleep	Long Idle	Short Idle
Baseline[1]	0.88	2.1	26.5	27.9

Efficient Equipment

The efficient measure is a desktop with a rating of Energy Star Version 6.0 rating, ES 6.0 +20%, ES 6.0 with 80 PLUS Gold PSUs, or ES 6.0 with 80 PLUS Platinum PSUs.

Measure Watt Draw in Mode (Watts)	Off	Sleep	Long Idle	Short Idle
ES 6.0 Desktops[2]	0.55	1.23	24.66	26.04
ES 6.0 +20% Desktops[3]	0.52	1.63	21.33	22.58
ES 6.0 Desktops w/ 80 PLUS Gold PSUs[4]	0.50	1.50	23.08	24.38
ES 6.0 Desktops w/ 80 PLUS Platinum PSUs[5]	0.50	1.50	22.19	23.44

Algorithms

Electric Demand Savings

ΔkW	$= (\text{Watts}_{Base,Long} - \text{Watts}_{Eff,Long})/1000$

Symbol Table

Electric Energy Savings

[6]

ΔkWh	$= 8760/1000 \times (((\text{Watts}_{Base,Off} \times \%\text{Time}_{Off}) + (\text{Watts}_{Base,Sleep} \times \%\text{Time}_{Sleep}) + (\text{Watts}_{Base,Long} \times \%\text{Time}_{Long}) + (\text{Watts}_{Base,Short} \times \%\text{Time}_{Short})) - ((\text{Watts}_{Eff,Off} \times \%\text{Time}_{Off}) + (\text{Watts}_{Eff,Sleep} \times \%\text{Time}_{Sleep}) + (\text{Watts}_{Eff,Long} \times \%\text{Time}_{Long}) + (\text{Watts}_{Eff,Short} \times \%\text{Time}_{Short})))$

Commercial Desktops	Off	Sleep	Long Idle	Short Idle	TEC (kWh/yr)	Savings (kWh/yr)	Demand Savings
Baseline	3.5	0.9	34.8	85.5	124.8	0.0	0.0000
ES 6.0 Desktops	2.2	0.5	32.4	79.9	115.0	9.8	0.0004
ES 6.0 Desktops +20% Desktops	2.0	0.7	28.0	69.2	100.0	24.7	0.0008
ES 6.0 Desktops w/ 80 PLUS Gold PSUs	2.0	0.7	30.3	74.7	107.7	17.1	0.0006
ES 6.0 Desktops w/ 80 PLUS Platinum PSUs	2.0	0.7	29.2	71.9	103.7	21.1	0.0007

Residential Desktops	Off	Sleep	Long Idle	Short Idle	TEC (kWh/yr)	Savings (kWh/yr)	Demand Savings
Baseline	3.4	4.4	27.9	12.7	48.4	0.0	0.0000
ES 6.0 Desktops	2.1	2.6	25.9	11.9	42.5	5.9	0.0003
ES 6.0 Desktops +20% Desktops	2.0	3.4	22.4	10.3	38.1	10.2	0.0006
ES 6.0 Desktops w/ 80 PLUS Gold PSUs	1.9	3.2	24.3	11.1	40.4	7.9	0.0005
ES 6.0 Desktops w/ 80 PLUS Platinum PSUs	1.9	3.2	23.3	10.7	39.1	9.3	0.0006

Symbol Table

Fossil Fuel Savings
N/A

Where:

$\%Time_{Long}$ = typical percent time in long idle mode

$\%Time_{Off}$ = typical percent of time a desktop, integrated desktop or notebook is in off mode during the year

$\%Time_{Short}$ = typical percent time in short idle mode

$\%Time_{Sleep}$ = typical percent time in sleep mode

ΔkW = gross customer connected load kW savings for the measure (kW)

ΔkWh = gross customer annual kWh savings for the measure (kWh)[7]

$Watts_{Eff,Off}$ = power in off mode

$Watts_{Base,Long}$ = power in long idle mode

$Watts_{Base,Sleep}$ = power in sleep mode

$Watts_{Eff,Long}$ = power in long idle mode

$Watts_{Eff,Short}$ = power in short idle mode

$Watts_{Eff,Sleep}$ = power in sleep mode

$Watts_{Base,Long}$ = power in long idle mode

$Watts_{Base,Off}$ = power in off mode

$Watts_{Base,Short}$ = power in short idle mode

$Watts_{Eff,Long}$ = power in long idle mode

Load Shapes

74a Internal Power Supply, Commercial Desktop
75a Internal Power Supply, Residential Desktop

Number	**Name**	**Status**	**Winter On kWh**	**Winter Off kWh**	**Summer On kWh**	**Summer Off kWh**	**Winter kW**	**Summer kW**
74	Internal Power Supply, Commercial Desktop	Active	39.2 %	27.5 %	19.6 %	13.7 %	50.0 %	80.0 %
75	Internal Power Supply, Residential Desktop	Active	33.8 %	32.9 %	16.9 %	16.4 %	52.2 %	40.5 %

Net Savings Factors

Measures

EQPCMPTR	Efficient Computers/Servers

Tracks [Base Track]

6032EPEP [is base track]	Efficient Products - Residential

Track Name	**Track Nr.**	**Measure Code**	**Free Rider**	**Spill Over**
Efficient Products - Residential	6032EPEP	EQPCMPTR	1.00	1.10

Lifetimes

The expected lifetime of the measure is 4 years.[8]

Measure Cost

The incremental cost for a 80 Plus Desktop PSU is $5.

The incremental cost for a Energy Star desktop PSU is $20.

[9]

Operating Hours

Measure Annual Mode Time (%)	Off	Sleep	Long Idle	Short Idle
Duty cycle - Commercial[10]	45%	5%	15%	35%
Duty cycle - Residential[11]	44%	24%	12%	5.2%

Footnotes

[1] Computer CASE Report, CA IOUs. http://www.energy.ca.gov/appliances/2013rulemaking/documents/proposals/12-AAER-2A_Consumer_Electronics/California_IOUs_Standards_Proposal_Computers_UPDATED_2013-08-06_TN-71813.pdf

[2] Analysis of current DT I2 category desktops in ES v6.0 QPL, available at http://www.energystar.gov/productfinder/product/certified-computers/results.

[3] Analysis of current DT I2 category desktops in ES v6.0 QPL, passing with > 20% margin.

[4] 80 PLUS program savings calculator, additional 6.4% savings over ES v6.0 Bronze PSU levels. Based on program measurements, available at http://www.80plus.org.

[5] 80 PLUS program savings calculator, additional 10% savings over ES v6.0 Bronze PSU levels.

[6] Desktop watt draw can be found in Reference Table at end of characterization.

[7] Algorithm comes from Energy Star Version 6.0 Guide

[8] Page 6 of Codes and Standards Enhancement (CASE) Initiative For PY 2013: Title 20 Standards Development, August 6, 2013. http://www.energy.ca.gov/appliances/2014-AAER-01/prerulemaking/documents/comments_12-AAER-2A/California_IOUs_Standards_Proposal_Addendum_Computers_2014-10-27_TN-73899.pdf

[9] Page 24: Research Into Action, 80 PLUS Market Progress Evaluation Report #6, November 26, 2013.

[10] ECMA 283, Appendix B, Majority Profile Study; ENERGY STAR v6.0 duty cycle. See https://www.energystar.gov/sites/default/files/specs//Version%206%201%20Computers%20Final%20Program%20Requirements.pdf.

[11] Energy Consumption of Consumer Electronics in U.S Homes in 2013, Fraunhofer, June 2014, Table 3-13, page 30

80 PLUS Servers

Measure Number:	IV-G-6 a
Portfolio:	92
Status:	Active
Effective Date:	2016/1/1
End Date:	[None]
Program:	Efficient Products Program
End Use:	Electronic Technology

Update Summary

- Updated to reflect newest ENERGY STAR criteria;
- Measure used to be a part of "Internal Power Supplies" TRM characterization. Internal Power Supplies characterization has been split into Desktops (completed as part of Portfolio 89 Update) and Servers updated here in Portfolio 92;

Referenced Documents

- Internal Power Supply Load Profile
- 80 PLUS Servers Calculator_Xcel_14Aug2014
- 2015-6 - Computer Efficiency - Power Supply TAs FINAL
- ENERGY STAR SERVERS Program_Requirements_V2
- ENERGY_STAR_Certified_Enterprise_Servers_20150803
- Server Power Supplies Data Points_PMO
- NREL_UMP Chapter 20

Description

Commercial customer incentives for installing servers with power supplies rated higher than 80 PLUS Silver[1]. At the moment, 80 PLUS Silver efficiency power supplies are most commonplace in the market and will serve as the baseline. 80 PLUS Gold, 80 PLUS Platinum, and 80 PLUS Titanium power supplies are eligible for incentive.

Baseline Efficiencies

The baseline efficiency for this measure is an 80 PLUS Silver server.

Efficient Equipment

The high efficiency for this measure is a server that is rated greater than 80 PLUS Silver. This includes 80 PLUS Gold, 80 PLUS Platinum, and 80 PLUS Titanium.

Algorithms

Electric Demand Savings

$$\Delta kW = (\text{PSU Watt}_{Baseline} / (1000 \times \text{Server Efficiency}_{Silver})) - (\text{PSU Watt}_{Efficient} / (1000 \times \text{Server Efficiency}_{Proposed})) + \text{Cooling Interaction kW}$$

Symbol Table

Electric Energy Savings

$$\Delta kWh = (\Delta kW \quad HOURS) + \text{Cooling Interaction kWh}$$

Where:

ΔkW	=	gross customer connected load kW savings for the measure
Cooling Interaction kW	=	Cooling load reduction based on tonnage[3]
Cooling Interaction kWh	=	Cooling load reduction based on cooling FLH[6]
HOURS	=	Hours of operation for the measure = 8760
PSU $\text{Watt}_{Baseline}$	=	Wattage of baseline power supply unit[4]

PSU Watt$_{Efficient}$ = Wattage of efficient power supply unit[5]

Server Efficiency$_{Proposed}$ = Refer to Table 1: Power Supply Efficiency

Server Efficiency$_{Silver}$ = Refer to Table 1: Power Supply Efficiency

Deemed Energy and Demand Savings[2]

Measure Description	Energy Savings (kWh)	Demand Savings (kW)
Computer Server; with <400W Units with Gold Rated Power Supply	43	0.01
Computer Server; with 400-600W Units with Gold Rated Power Supply	71	0.01
Computer Server; with 600-1000W Units with Gold Rated Power Supply	107	0.01
Computer Server; with >1000W Units with Gold Rated Power Supply	200	0.02
Computer Server; with <400W Units with Platinum Rated Power Supply	83	0.01
Computer Server; with 400-600W Units with Platinum Rated Power Supply	138	0.02
Computer Server; with 600-1000W Units with Platinum Rated Power Supply	207	0.03
Computer Server; with >1000W Units with Platinum Rated Power Supply	386	0.05
Computer Server; with <400W Units with Titanium Rated Power Supply	116	0.01
Computer Server; with 400-600W Units with Titanium Rated Power Supply	193	0.02
Computer Server; with 600-1000W Units with Titanium Rated Power Supply	290	0.04
Computer Server; with >1000W Units with Titanium Rated Power Supply	541	0.07

Load Shapes

Desktop and Datacenter Server.[7]

25a Flat (8760 hours)

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
25	Flat (8760 hours)	Active	31.7 %	34.9 %	15.9 %	17.5 %	100.0 %	100.0 %

Net Savings Factors

Measures

EQPCMPTR	Efficient Computers/Servers

Tracks [Base Track]

6032EPEP [is base track]	Efficient Products - Residential

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Efficient Products - Residential	6032EPEP	EQPCMPTR	1.00	1.10

Lifetimes

Measure life[8] is based on an estimated server life of 5 years.

Measure Cost

The incremental cost for the 80 PLUS Servers are as follows:

- Gold: $15
- Platinum: $40
- Titanium: $75

Reference Tables

Table 1: Power Supply Efficiency[9]

Loading	Silver	Gold	Platinum	Titanium

5%	75.1%	80.2%	85.6%	90.6%
10%	79.0%	83.4%	87.9%	92.1%
15%	82.9%	86.5%	90.2%	93.5%
20%	86.8%	89.6%	92.5%	94.9%
30%	88.0%	90.6%	93.1%	95.3%
40%	89.2%	91.5%	93.7%	95.8%
50%	90.4%	92.5%	94.3%	96.2%
60%	90.1%	92.2%	94.0%	95.9%
70%	89.8%	92.0%	93.7%	95.6%
80%	89.5%	91.8%	93.4%	95.3%
90%	89.2%	91.5%	93.2%	95.1%
100%	88.9%	91.3%	92.9%	94.8%

Footnotes

[1] 80 PLUS servers website: http://www.plugloadsolutions.com/80pluspowersupplies.aspx.

[2] Refer to Electric Forecast Summary tab in the document: 2015-6 - Computer Efficiency - Power Supply TAs FINAL.xlsx

[3] Refer to the analysis file for calculation of Cooling Interaction kW: 2015-6 - Computer Efficiency - Power Supply TAs FINAL.XLSX

[4] This is calculated by multiplying baseline input wattage x number of power supplies x load factor. This analysis can be found in 2015-6 - Computer Efficiency - Power Supply TAs FINAL.XLSX

[5] his is calculated by multiplying efficient input wattage x number of power supplies x load factor. This analysis can be found in 2015-6 - Computer Efficiency - Power Supply TAs FINAL.XLSX

[6] Refer to the analysis file for calculation of Cooling Interaction kWh: 2015-6 - Computer Efficiency - Power Supply TAs FINAL.XLSX

[7] See < *Internal Power Supply Load Profile.x*ls>

[8] NREL, *The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures*, Chapter 20 Data Center IT Efficiency Measures, January 2015 (Page 17.)

[9] 2015-6 - Computer Efficiency - Power Supply TAs FINAL.XLSX supplied by Ecova on 4/14/2016

ENERGY STAR Heat Pump Water Heater

Measure Number: IV-I-1 c
Portfolio: 96
Status: Active
Effective Date: 2016/1/1
End Date: [None]
Program: Efficient Products Program
End Use: Hot Water

Update Summary

Referenced Documents

- VT SF Existing Homes Onsite Report_final 021513
- HPWH_TRM_Analysis_Retrofit_Low_Income_2016
- NEEA Spec Qualified-Products-List
- NEEA HPWH Advanced Water Heater Spec 05-17-16
- HPWH_TRM_Analysis__Non_NEEA_Spec_2016
- HPWH_TRM_Analysis__NEEA_Spec_2017

Description

This measure charaterization provides documentation of prescriptive savings estimates for the installation of Heat Pump Water Heater (HPWH) in place of a baseline water heater in a residential application. The measure is characterized for both market opportunity and retrofit applications. Retrofit savings only apply for direct install low-income program applications[1]. Savings are presented dependent on the existing water heater fuel type, Federal Standards, and HPWH storage volume. HPWH efficiency has been reduced to account for differences in field performance versus rated efficiency due to ambient conditions, hot water demand, and other factors, and a heating penalty is assessed to account for the impact of the heat pump water heater on the home’s heating load.

The prescriptive savings tables provide saving estimates for program year 2016 and program year 2017 and on. In program year 2017 Efficiency Vermont Heat Pump Water program adopted the NEEA Northern Climate Specification, which provides added energy efficiency guidance to manufacturers developing HPWHs. The updated equipment specification is known as the Advanced Water Heater Specification.

Homes with existing natural gas water heaters are not eligible for savings under this measure.

Algorithms

Electric Demand Savings

The reduction (or increase) in electric demand due to the installation of a HPWH is derived below based on prescriptive energy savings found in **Table 4**.

ΔkW $= \Delta kWh / Hours$

Symbol Table

Electric Energy Savings

For cases where this measure is installed in a home with an existing electric resistance water heater or in a new construction project, electric savings account for the improvement in performance of a HPWH over a baseline electric resistance water heater. For homes with existing fossil fuel water heaters, the installation of a HPWH results in an electric penalty equal to the annual electricity use of the water heater to rerpresent the added electric load. In both caseas a penalty is taken to account for the heating load placed on a home’s heating system by the HPWH, apportioned based on the percentage of homes in Vermont with electric heat.

For prescriptive purposes, savings and penalties will be assigned using deemed values, outlined in **Table 4**.

ΔkWh $= \Delta EF_{Elec} \times Q_{DHW} \times (1 - PF\_ElecHeat)$

ΔEF_{Elec} $= (1/EF_{ElecBASE} – 1/EF_{HPWh})$ for homes with existing electric water heaters and new homes

ΔEF_{Elec} $= – 1/EF_{HPWh}$ for homes with existing fossil fuel fired water heaters

$PF\_ElecHeat$ $= WHHF \times \%HeatSource / COP \times ExistDHWElec$

Symbol Table

Fossil Fuel Savings

For homes with existing fossil fuel water heaters, fuel switching results in fuel savings equal to the annual fuel use that would have resulted if a baseline fossil fuel fired water heater had been installed in the home. For upstream measures where fossil fuel type may be unknown, savings are apportioned based on the breakdown of water heating fuels in Vermont homes, excluding natural gas. A fossil fuel penalty is taken to account for the heating load placed on a home's heating system by the HPWH. For prescriptive purposes, this increased heating usage is allocated by fuel type based on the breakdown of primary heating fuel types in Vermont homes, excluding natural gas.

Savings and penalties will be assigned using deemed values, outlined in **Table 4**.

ΔMMBtu	= (SF_FF_DHW – PF_FF_Heating)
SF_FF_DHW	$= 1/EF_{FFBASE} \times Q_{DHW} \times$ ExistDHWFF × %DHWFuel
PF_FF_Heating	$= \Delta EF_{Elec} \times Q_{DHW} \times$ WHHF × %HeatSource / ηHeat × ExistDHWElec

Symbol Table

Water Savings

Where:

%DHWFuel = This factor apportions fuel savings for homes with unknown fuel types, a prescreening is conducted to exclude homes with existing natural gas water heaters.[11]

= 1 if the existing water heater fuel type is known, all savings attributed to that fuel type

=76% for fuel oil, if fuel type is unknown

= 24% for propane, if fuel type is unknown

%HeatSource = = portion of homes with electric space heat

= 5%[2]

= 61% for fuel oil[3]

= 17% for propane

= 17% for Wood/Other

ΔEF_{Elec} = $=(1/EF_{ElecBASE} - 1/EF_{HPWH})$ for homes with existing electric water heaters and new homes

$=- 1/EF_{HPWH}$ for homes with existing fossil fuel fired water heaters

ΔkWh = $\Delta EF_{Elec} * Q_{DHW} * (1 - PF\_ElecHeat)$

ηHeat = = 84.2% for fuel oil[12]

= 87.4% for propane

= 65% for Wood/Other

COP = Coefficient of Performance of electric space heating system

=2.4[4]

EF_{HPWh} = =Energy Factor of heat pump water heater – prescriptive value based on NEEA Northern Climate Energy Factor[5]

= Rated EF (prescriptive value from **Table 4 below**)

$EF_{ElecBASE}$ = Energy Factor (efficiency) of baseline electric water heater[6]

= Refer to table below

Fuel	Tank Volume	Energy Factor
Electric	All	0.95

EF_{FFBASE} = Energy Factor (efficiency) of baseline fossil fuel water heater

= 0.60 for propane water heaters ≥ 20 gal and ≤ 55 gal

=0.75 for propane water heaters > 55 gal and ≤ 100 gal

= 0.59 for fuel oil water heaters

= 0.59 for fossil fuel water heaters with unknown fuel type.

ExistDHWElec = = 1 if the home has an existing electric water heater[7]

= –1 if the home has an existing fossil fuel fired water heater

ExistDHWFF = =1 if the home has an existing fossil fuel fired water heater

= 0 if the home has an existing electric water heater

Hours = Full load hours of water heater

= 2533

PF_ElecHeat = Heating penalty factor from conversion of electric heat in home to water heat

= WHHF * %HeatSource / COP * ExistDHWElec

PF_FF_Heating = Heating penalty factor from conversion of noneletric heat in home to water heat

= - ΔEF_{Elec} * Q_{DHW} * WHHF * %HeatSource / ηHeat * ExistDHWElec

Q_{DHW} = Heat delivered to water in HPWH tank annually

= 2,618 kWh[8]

=8.93 MMBtu[9]

SF_FF_DHW = Savings from fuel switching, accounts for replacement of baseline fossil fuel fired water heater by HPWH

= 1/EF_{FFBASE} * Q_{DHW} * ExistDHWFF * %DHWFuel

WHHF = Portion of reduced waste heat that results in increased heating

=0.512[10]

Baseline Efficiencies

The baseline condition for a market opportunity heat pump water heater is assumed to be a new water heater that uses the same fuel as the home's existing water heater and follows the current Federal Standard for residential water heaters[13].

The baseline condition for a low income retrofit heat pump water heater is the existing electric water heater.

High Efficiency

To qualify for this measure the installed equipment must be NEEA Tier 1, II, or III certified heat pump water heater[14] or a heat pump water heater that fulfills the ENERGY STAR specification.

Operating Hours

2533 full load hours per year

Load Shapes

6a Residential DHW fuel switch

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
6	Residential DHW fuel switch	Active	40.2 %	32.0 %	15.1 %	12.7 %	40.1 %	20.3 %

Net Savings Factors

Measures

HWEHWHTP	ENERGY STAR Heat Pump Water Heater

Tracks [Base Track]

6032EPEP [is base track]	Efficient Products - Residential

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Efficient Products - Residential	6032EPEP	HWEHWHTP	1.00	1.10

Persistence

The persistence factor is assumed to be one.

Lifetimes

The expected measure life is assumed to be 13 years. For retrofit measures, it is assumed that the existing water heating equipment has five years of remaining life and would be replaced with baseline equipment with the associated installed cost at end of life. Analysis period is the same as the lifetime.

Measure Cost

For measures installed in a market opportunity situation, the measure cost is the incremental cost for the installation of a HPWH versus baseline equipment based on the existing water heater fuel type. For retrofit measures, the measure cost is the full cost for the installation of a HPWH[15].

Table 3 – Measure Costs

Installation	HPWH Volume	Baseline EF	Incremental Cost
Existing electric DHW	≤55	0.95	$818
Existing electric DHW	>55	0.95	$992
Existing propane fired DHW	≤55	0.60	$818
Existing propane fired DHW	>55	0.60	$992
Existing fuel oil fired DHW	≤55	0.59	$818
xisting fuel oil fired DHW	>55	0.59	$992
Existing fuel unknown DHW	≤55	0.59	$818
Existing fuel unknown DHW	>55	0.59	$992

O&M Cost Adjustments

There are no operation and maintenance cost adjustments for this measure.

Fossil Fuel Description

For homes with existing fossil fuel water heaters, fuel switching results in fuel savings equal to the annual fuel use that would have resulted if a baseline fossil fuel fired water heater had been installed in the home. For upstream measures where fossil fuel type may be unknown, savings are apportioned based on the breakdown of water heating fuels in Vermont homes, excluding natural gas. A fossil fuel penalty is taken to account for the heating load placed on a home's heating system by the HPWH. For prescriptive purposes, this increased heating usage is allocated by fuel type based on the breakdown of primary heating fuel types in Vermont homes, excluding natural gas.

Savings and penalties will be assigned using deemed values, outlined in **Table 4**.

Prescriptive Savings

For prescriptive purposes this measure has been binned based on HPWH energy factor and existing water heater fuel type as follows:

Table 4 – Prescriptive Savings Values[16]

<u>**Prescriptive Savings Table for Program Year 2016:**</u>

Storage Volume	≤ 55 gallons						≤ 55 gallons					
Existing DHW Fuel	Electric			Fuel Oil			Propane			Unknown Fossil Fuel		
EF Spec	EF<2.7	2.7	3.2	EF<2.7	2.7	3.2	EF<2.7	2.7	3.2	EF<2.7	2.7	3.2
Average EF	1.82	2.08	2.41	1.82	2.08	2.41	1.82	2.08	2.41	1.82	2.08	2.41
ΔkWh	1319.46	1495.71	1665.72	-1452.44	-1272.39	-1098.71	-1452.44	-1272.39	-1098.71	-1452.44	-1272.39	-1098.71
ΔkW	0.52	0.59	0.66	-0.57	-0.50	-0.43	-0.57	-0.50	-0.43	-0.57	-0.50	-0.43
ΔMMBtu Propane	-1.67	-1.90	-2.11	-1.80	-1.58	-1.36	13.09	13.31	13.53	1.86	2.09	2.30
ΔMMBtu Fuel Oil	-0.46	-0.53	-0.59	14.77	14.83	14.89	-0.50	-0.44	-0.38	11.11	11.17	11.23
ΔMMBtu Wood	-0.63	-0.71	-0.79	-0.67	-0.59	-0.51	-0.67	-0.59	-0.51	-0.67	-0.59	-0.51
Measure life (yrs)	13	13	13	13	13	13	13	13	13	13	13	13
Incremental cost ($)	818	818	818	818	818	818	818	818	818	818	818	818

Storage Volume	> 55 gallons											
Existing DHW Fuel	Electric			Fuel Oil			Propane			Unknown Fossil Fuel		
EF Spec	EF<2.7	2.7	3.2	EF<2.7	2.7	3.2	EF<2.7	2.7	3.2	EF<2.7	2.7	3.2
Average EF	2.17	2.71	2.96	2.17	2.71	2.96	2.17	2.71	2.96	2.17	2.71	2.96
ΔkWh	1549.80	1786.29	1867.04	-1217.13	-975.54	-893.05	-1217.13	-975.54	-893.05	-1217.13	-975.54	-893.05
ΔkW	0.61	0.71	0.74	-0.48	-0.39	-0.35	-0.48	-0.39	-0.35	-0.48	-0.39	-0.35
ΔMMBtu Propane	-1.98	-2.28	-2.39	-1.52	-1.22	-1.12	10.36	10.66	10.76	10.08	10.39	10.49
ΔMMBtu Fuel Oil	-0.53	-0.61	-0.64	14.86	14.94	14.97	-0.41	-0.33	-0.30	3.26	3.34	3.37
ΔMMBtu Wood	-0.72	-0.82	-0.86	-0.55	-0.44	-0.40	-0.55	-0.44	-0.40	-0.55	-0.44	-0.40
Measure life (yrs)	13	13	13	13	13	13	13	13	13	13	13	13

Incremental cost ($)	992	992	992	992	992	992	992	992	992	992	992	992

Prescriptive Savings Table for Program Year 2017 and on:

Storage Volume	≤ 55 gallons											
Existing DHW Fuel	Electric			Fuel Oil			Propane			Unknown Fossil Fuel		
NEEA Spec Tier	Tier 1	Tier 2	Tier 3	Tier 1	Tier 2	Tier 3	Tier 1	Tier 2	Tier 3	Tier 1	Tier 2	Tier 3
Average EF	2.09	2.20	2.92	2.09	2.20	2.92	2.09	2.20	2.92	2.09	2.20	2.92
ΔkWh	1501.78	1563.76	1854.30	-1266.18	-1202.87	-906.06	-1266.18	-1202.87	-906.06	-1266.18	-1202.87	-906.06
ΔkW	0.59	0.62	0.73	-0.50	-0.47	-0.36	-0.50	-0.47	-0.36	-0.50	-0.47	-0.36
ΔMMBtu Propane	-1.90	-1.98	-2.35	-1.57	-1.49	-1.12	13.32	13.40	13.77	2.09	2.17	2.54
ΔMMBtu Fuel Oil	-0.53	-0.55	-0.65	14.84	14.86	14.96	-0.44	-0.41	-0.31	11.17	11.19	11.29
ΔMMBtu Wood	-0.71	-0.74	-0.88	-0.59	-0.56	-0.42	-0.59	-0.56	-0.42	-0.59	-0.56	-0.42
Measure life (yrs)	13	13	13	13	13	13	13	13	13	13	13	13
Incremental cost ($)	818	818	818	818	818	818	818	818	818	818	818	818

Storage Volume	>55 gallons											
Existing DHW Fuel	Electric			Fuel Oil			Propane			Unknown Fossil Fuel		
NEEA Spec Tier	Tier 1	Tier 2	Tier 3	Tier 1	Tier 2	Tier 3	Tier 1	Tier 2	Tier 3	Tier 1	Tier 2	Tier 3
Average EF	2.15	2.00	3.05	2.15	2.00	3.05	2.15	2.00	3.05	2.15	2.00	3.05
ΔkWh	1538.66	1446.01	1892.90	-1228.51	-1323.16	-866.63	-1228.51	-1323.16	-866.63	-1228.51	-1323.16	-866.63
ΔkW	0.61	0.57	0.75	-0.49	-0.52	-0.34	-0.49	-0.52	-0.34	-0.49	-0.52	-0.34
ΔMMBtu Propane	-1.97	-1.85	-2.42	-1.54	-1.66	-1.08	10.34	10.22	10.79	10.07	9.95	10.52
ΔMMBtu Fuel Oil	-0.53	-0.50	-0.65	14.86	14.83	14.98	-0.41	-0.44	-0.29	3.25	3.22	3.37
ΔMMBtu Wood	-0.71	-0.67	-0.87	-0.56	-0.60	-0.39	-0.56	-0.60	-0.39	-0.56	-0.60	-0.39
Measure life (yrs)	13	13	13	13	13	13	13	13	13	13	13	13
Incremental cost ($)	992	992	992	992	992	992	992	992	992	992	992	992

Low Income Program Savings:

	GE Model: GEH50DEEJSC	State HPX-66-DHPT 100	GE GEH80DEEJSC
	Low Income Retrofit		
Existing DHW Fuel	Electric		
Calculated EF	2.51	2.85	2.93
ΔkWh	1814	1939	1964
ΔkW	0.72	0.77	0.78
Measure life (yrs)	13	13	13
Retrofit cost ($)	$ 1,575	$ 1,703	$ 1,703
Gallons	50	66	80

Footnotes

[1] The Efficiency Vermont Retrofit program for HPWH has incentives only on three qualifying HPWH that replace existing electric resistance water heaters.

[2] Split of primary heating fuels from the VT SF Existing Homes Onsite Report Table 5-1 after removing homes with natural gas space heat (NMR Group, Inc. 2013).

[3] Split of primary heating fuels from the VT SF Existing Homes Onsite Report Table 5-1 after removing homes with natural gas space heat. (NMR Group, Inc. 2013).

[4] The COP used here is an assumption based upon Vermont Department of Public Service assumptions in fuel cost reports .

[5] NEEA Advanced Water Heater Specification, June 24, 2016. NEEA Spec Qualified-Products-List.pdf

[6] Federal Appliance Standards for new Baseline, effective April 16, 2015. Table 2. Amended Energy Conservation Standards for Residential Water Heaters. Refer to HPWH_TRM_Analysis_NEEA_Spec_2017.xlsx, Baseline EF tab.

[7] This factor ensures proper accounting of the heating penalty dependent on the fuel type of the home's existing water heater.

[8] Average annual DHW heat input for Vermont homes, derived from metered data for homes on CVPS Rate 3: Off-Peak Water Heating rate. See Q_{DHW} in HPWH_TRM_Analysis_NEEA_Spec_2017.xlsx.

[9] Average annual DHW heat input for Vermont homes, derived from metered data for homes on CVPS Rate 3: Off-Peak Water Heating rate. See Q_{DHW} in HPWH_TRM_Analysis__NEEA_Spec_2017.xlsx.

[10] Based on bin analysis of annual heating hours for Burlington, VT using TMY3 data: 4484 / 8760 = 51.2%. See Heating Penalty in HPWH_TRM_Analysis_NEEA_Spec_2017.xlsx.

[11] This factor apportions fuel savings for homes with unknown fuel types, a prescreening is conducted to exclude homes with existing natural gas water heaters.

[12] Weighted efficiencies based on VT SF Existing Homes Onsite Report Table 5-8 and 5-9. (NMR Group, Inc. 2013). Efficiency for homes using wood or pellet stoves based on review of EPA-Certified wood stoves (U.S. Environmental Protection Agency n.d.)

[13] Federal Appliance Standards for new Baseline, effective April 16, 2015. Table 2. Amended Energy Conservation Standards for Residential Water Heaters. Refer to HPWH_TRM_Analysis_NEEA_Spec_2017.xlsx, Baseline EF tab.

[14] Refer to NEEA HPWH Advanced Water Heater Spec 05-17-16 for NEEA Tier Specifications. Refer to NEEA Spec HPWH tab on analysis documents: HPWH_TRM_Analysis_NEEA_Spec_2017.xlsx

[15] NEEP Incremental Cost- Emerging Technology, 2016. http://www.neep.org/incremental-cost-emerging-technology-0. Refer to Incremental Costs tab of HPWH_TRM_Analysis__NEEA_Spec_2017.xlsx.

[16] See HPWH_TRM_Analysis_Retrofit_Low_Income_2016.xlsx and HPWH_TRM_Analysis__NEEA_Spec_2016.xlsx for derivation of savings. Prescriptive EF for each bin based on average EF of ENERGY STAR certified water heaters for each EF range.

Thermostatically Initiated Shower Restriction Valve

Measure Number: IV-I-2 c
Portfolio: EVT TRM Portfolio 2018-03
Status: Active
Effective Date: 2018/1/1
End Date: [None]
Program: Efficient Products Program
End Use: Hot Water

Update Summary

Update to revise the implementation method for this measure to free giveaways of products that are requested by customers.

Referenced Documents

- Cadmus_Ameren Missouri EP Impact & Process Evaluation_May 2016
- Cadmus_Showerhead and Faucet Aerator Meter Study_June 2013
- Navigant_energySMART Energy Savings Kits_Apr 2016
- U.S. Census Bureau_ACS Table DP04 Vermont_2015
- U.S. DOE_Building America Standard DHW Schedules_May 2014
- Sherman_Disaggregating Residential Shower Warm-Up Waste_Aug 2014
- EVT_Shower Restriction Valve_Analysis_Feb 2018_v2

Description

This measure relates to the installation of a thermostatically initiated shower restriction valve in a home. The valve prevents hot water waste during shower warm-up by closing off flow once hot water has reached the fixture. The valve is reopened manually by pulling down on a connected cord. Once flow has been cut off after the shower, the valve resets itself. This measure applies to free giveaways to customers who request products.

Baseline Efficiencies

The baseline is no restriction valve in place.

Efficient Equipment

The efficient condition is a thermostatically initiated shower restriction valve used in conjunction with a standard showerhead.

Algorithms

Electric Demand Savings

ΔkW = ΔkWh/HOURS

Symbol Table

Electric Energy Savings

ΔkWh = ((GPM × WasteTime × # people × # showers × usedays/year / SH/home × 8.3 × 1.0 × (TEMP$_{sh}$ - TEMP$_{in}$)) / ηElectric_DHW / 3,412) x ISR x %Electric_DHW

Symbol Table

Fossil Fuel Savings

ΔMMBtu = ((GPM × WasteTime × # people × # showers × usedays/year / SH/home × 8.3 × 1.0 × (TEMP$_{sh}$ - TEMP$_{in}$)) / ηFuel_DHW / 1,000,000) x ISR x %Fuel_DHW

Symbol Table

Water Savings

ΔCCF = GPM × WasteTime × # people × # showers × usedays/year/ SH/home / 748 x ISR

Where:

people = Average number of people per household
= 2.33[2]

showers = Showers per person per day

= 0.6[3]

%Electric_DHW = Proportion of water heating supplied by electricity

= 25%[4]

%Fuel_DHW = Proportion of water heating supplied by fuel oil, natural gas, or propane[4]

Fuel Oil	**Natural Gas**	**Propane**
20%	26%	27%

ΔCCF = Gross customer annual water savings for the measure

See Reference Tables section for deemed savings values.

ΔkW = Gross customer connected load kW savings for the measure

See Reference Tables section for deemed savings values.

ΔkWh = Gross customer annual kWh savings for the measure

See Reference Tables section for deemed savings values.

ΔMMBtu = Gross customer annual MMBtu savings for the measure

See Reference Tables section for deemed savings values.

ηElectric_DHW = Recovery efficiency of electric water heater

= 0.98[5]

ηFuel_DHW = Recovery efficiency of fuel water heater

= 0.78[12]

1,000,000 = Conversion factor from Btu to MMBtu

1.0 = Specific heat of water (Btu/lb-°F) (constant)

3,412 = Conversion factor from Btu to kWh

748 = Constant to convert from gallons to CCF

8.3 = Constant to convert gallons to lbs

GPM = Flow rate (gpm) of showerhead

= 2.5 gpm[6]

HOURS = Annual full load hours

= 3,427.1 hours[1]

ISR = In service rate, or the percentage of units rebated that are actually installed

= 45%[7]

SH/home = Average number of showerheads per household

= 1.3*[8]*

$TEMP_{in}$ = Assumed temperature of water entering house

= 51.9 F[9]

$TEMP_{sh}$ = Assumed temperature of water coming from showerhead

= 101 F[10]

usedays/year = Days showerhead is used per year

= 365

WasteTime = Average hot water waste time (minutes) avoided per shower due to restriction valve

= 0.88[11]

Load Shapes

For DHW systems not on Utility Controlled DHW program (Default): Loadshape #8, Residential DHW Conservation;

For DHW systems on Utility Controlled DHW program: Loadshape #54, Controlled DHW Conservation;

Loadshapes #8 and #54 are based on Itron 8760 hourly load data.

8a Residential DHW conserve
54a Controlled DHW Conservation

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
8	Residential DHW conserve	Active	48.7 %	29.1 %	14.3 %	7.9 %	40.1 %	20.3 %
54	Controlled DHW Conservation	Active	48.7 %	29.1 %	14.3 %	7.9 %	20.5 %	12.1 %

Net Savings Factors

Measures

HWESHTRV	Thermostatically Initiated Shower Restriction Valve

Tracks [Base Track]

6034LISF [is base track]	LISF Retrofit
6036RETR [is base track]	Res Retrofit

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Res Retrofit	6036RETR	HWESHTRV	0.90	1.00
LISF Retrofit	6034LISF	HWESHTRV	1.00	1.00

Lifetimes

The measure life is assumed to be 10 years.[13]

Measure Cost

The measure cost for free giveaways is the actual program cost of a new shower valve: $16.75.

Reference Tables

Savings are presented below.[14]

ΔkW	ΔkWh	ΔMMBtu (fuel oil)	ΔMMBtu (natural gas)	ΔMMBtu (propane)	ΔCCF
0.00345	11.8	0.041	0.053	0.055	0.52

Footnotes

[1] Full load hours from Loadshape #8a (Residential DHW Conserve) and #54a (Controlled DHW Conservation).

[2] Weighted average household size of owner-occupied versus renter-occupied housing units ((71% * 2.42) + (29% * 2.12)) based on 2011-2015 American Community Survey 5-Year Estimates for Vermont. See reference file U.S. Census Bureau_ACS Table DP04 VT_2015.pdf.

[3] Cadmus and Opinion Dynamics, for the Michigan Evaluation Working Group, "Showerhead and Faucet Aerator Meter Study Memorandum," June 2013, page 11, Table 8.

[4] DHW fuel percentages for free products based on data received by Efficiency Vermont on 08/21/2017 from the upcoming NMR Vermont Residential Market Assessment.

[5] Review of AHRI database shows that electric water heaters have a recovery efficiency of 98%.

Note that during November 2017 TAG, EVT and DPS agreed that assumptions for HPWH will be added during the next TRM reliability update cycle in 2020.

[6] The Energy Policy Act of 1992 (EPAct) established the maximum flow rate for showerheads at 2.5 gallons per minute (gpm).

[7] In the absence of evaluation studies supporting an ISR for free shower restriction valves, EVT began with the ISR assumption for low-flow showerheads (56%) from the Home Energy Kits measure: "Average of showerhead in service rate for kits including one showerhead (65%) from Navigant, "energySMART Energy Savings Kits, GPY 4 Evaluation Report (FINAL)," April 29, 2016, p. 20, and kits showerhead in service rate for single family homes (47%) from Cadmus, "Ameren Missouri Efficient Products Impact and Process Evaluation: PY 2015," May 13, 2016, p. 23." EVT reduced the ISR to 45% for shower restriction valves since customers are likely to be less familiar with these products.

[8] Average of values for single family and multifamily households from Cadmus and Opinion Dynamics, for the Michigan Evaluation Working Group,

"Showerhead and Faucet Aerator Meter Study Memorandum," June 2013, page 12, Table 9.

[9] Average value for Burlington, Montpelier. Rutland, and Springfield, VT from U.S. DOE Standard Building America DHW Schedules, May 2014.

[10] Cadmus and Opinion Dynamics, for the Michigan Evaluation Working Group, "Showerhead and Faucet Aerator Meter Study Memorandum," June 2013, page 11, Table 7.

[11] Average of values from Troy Sherman, "Disaggregating Residential Shower Warm-Up Waste: An Understanding and Quantification of Behavioral Waste Based on Data from Lawrence Berkeley National Labs," August 11, 2014, p. 11 and Cadmus and PPL Electric, "Pilot Study for a Thermostatic Shower Restriction Valve," 2015, p. 6, Table 4.

[12] Based on a review of fuel DHW systems available in AHRI database.

[13] California DEER Ex Ante Database

[14] See file EVT_Shower Restriction Valve_Analysis_Feb 2018_v2.xlsx for calculation details.

Advanced Thermostats

Measure Number:	IV-J-2 b
Portfolio:	EVT TRM Portfolio 2017-05
Status:	Inactive
Effective Date:	2017/1/1
End Date:	2018/12/31
Program:	Efficient Products Program
End Use:	HVAC

Update Summary

New measure to characterize savings for advanced thermostats, for both existing homes and new construction.

Referenced Documents

- VT-RES-New-Construction-On-Site-Final-Report-2-13-13
- IL SAG Smart Thermostat Preliminary Gas Impact Findings 2015-12-08 to IL SAG
- Studies informing the TRM Savings Characterization for Advanced Thermostats
- VT SF Existing Homes Onsite Report_final 021513
- Advanced Thermostat Analysis_04182017_FINAL
- VGS Usage Regression Work_04182017
- Programmable Thermostats Furnace Fan Analysis

Description

This measure characterizes the household energy savings from the installation of a new thermostat(s) for reduced heating and cooling consumption through a configurable schedule of temperature set-points (like a programmable thermostat) *and* automatic variations to that schedule to better match HVAC system runtimes to meet occupant comfort needs. These schedules may be defaults, established through user interaction, and be changed manually at the device or remotely through a web or mobile app. Automatic variations to that schedule could be driven by local sensors and software algorithms, and/or through connectivity to an internet software service. Data triggers to automatic schedule changes might include, for example: occupancy/activity detection, arrival & departure of conditioned spaces, optimization based on historical or population-specific trends, weather data and forecasts.[1] This class of products and services are relatively new, diverse, and rapidly changing. Generally, the savings expected for this measure aren't yet established at the level of individual features, but rather at the system level and how it performs overall. Note that it is a very active area of ongoing study to better map features to savings value, and establish standards of performance measurement based on field data so that a standard of efficiency can be developed. That work is not yet complete but does inform the treatment of some aspects of this characterization and recommendations.

Savings estimates are provided for Existing Homes and New Construction. Note all savings will be claimed through Efficient Products, however the baseline for New Construction is a programmable thermostat (due to code requirements) while the baseline for Existing Homes is assume to be a mix of manual and programmable thermostats.

The measure assumes that the advanced thermostat is controlling a portion of the whole home's heating/cooling load. Efficiency Vermont will track and provide incentives for up to two advanced thermostats per home.

The thermostat must be installed and connected with the manufacturer in order to be eligible for a rebate.

Baseline Efficiencies

For existing homes the baseline is assumed to be a mix of programmable and manual thermostats (67% manual and 33% programmable - based upon Vermont Single-Family Existing Homes Onsite Report, 2/15/2013, 'Table 5-13 Type of Thermostat').

For New Construction, the baseline is a programmable thermostat.

Efficient Equipment

The criteria for this measure are established by replacement of a manual-only or programmable thermostat, with one that has the default enabled capability—or the capability to automatically—establish a schedule of temperature setpoints according to driving device inputs above and beyond basic time and temperature data of conventional programmable thermostats. As summarized in the description, this category of products and services is broad and rapidly advancing in regards to their capability, usability, and sophistication, but at a minimum must be capable of two-way communication[2] and exceed the typical performance of manual and conventional programmable thermostats through the automatic or default capabilities described above.

Algorithms

Electric Demand Savings

ΔkW	$= Max(\Delta kWh_{heating} / EFLH_{heat} , \Delta kWh_{cooling} / EFLH_{cool})$

Symbol Table

Electric Energy Savings

$\Delta kWh = \Delta kWh_{heating} + \Delta kWh_{cooling}$

$\Delta kWh_{heating} = \%ElectricHeat \times Elec\_Heating\_Consumption \times \%Controlled \times Heating\_Reduction + (\Delta MMBtu \times F_e \times 293)$

$\Delta kWh_{cooling} = \%AC \times ((EFLH_{cool} \times Capacity \times 1/SEER)/1000) \times Cooling\_Reduction$

Symbol Table

Fossil Fuel Savings

$\Delta MMBtu = \Sigma\ (\%FossilHeat \times Heating\_Consumption \times \%Controlled) \times Heating\_Reduction$

Where:

%AC = Fraction of customers with central air-conditioning

Central air conditioning?	%AC	
	Existing Homes	New Construction
Yes	100%	
No	0%	
Unknown	3.5%[5]	8.2%[6]

%Controlled = Assumed percentage of total heating load being controlled by thermostat.

= 69% for EH and 53% for RNC[7]

%ElectricHeat = Percentage of heating savings assumed to be electric

Heating fuel	%ElectricHeat	
	Existing Homes	New Construction
Electric	100%	
Fossil Fuel	0%	
Unknown	0%[8]	0%[9]

%FossilHeat = Percentage of heating savings assumed to be fossil fuel (note for the 'unknown' category natural gas is not included as it will be known that it is not natural gas)

Heating fuel		%FossilHeat	
		Existing Homes[17]	New Construction[18]
Electric		0%	
Fossil Fuel		100%	
Unknown	Oil	78%	13%
	Propane	22%	87%

ΔkW = Annual demand reduction.

$\Delta kWh_{cooling}$ = Electric savings from cooling energy usage reductions

$\Delta kWh_{heating}$ = Electric savings from heating energy usage reductions. This accounts for both electric heat (heat pumps) and fan/pump savings in the case of a fossil heating system.

ΔkWh = Electrical savings are a function of both heating and cooling energy usage reductions.

ΔMMBtu = Fuel savings if fossil fuel heating system

293 = kWh per MMBtu

Capacity = Capacity of AC unit. (Note: One refrigeration ton is equal to 12,000 Btu/hr.)

= 41,400 Btuh/hr[10]

Cooling_Reduction = Assumed percentage reduction in total household cooling energy consumption due to installation of advanced thermostat

= 8.0%[11]

$EFLH_{cool}$ = Estimate of annual household full load cooling hours for air conditioning equipment.

= 375[3]

$EFLH_{heat}$ = Assumed Equivalent Full Load Hours for heating

EFLH[4]	
Existing Homes	**New Construction**
878	855

Elec_Heating_Consumption = Estimate of annual household heating consumption for heat pump heated homes:

Elec_Heating_Consumption (kWh)	
Existing Homes	**New Construction**
8,273[12]	6,416[13]

F_e = Furnace fan / boiler pump energy consumption as a percentage of annual fuel consumption

= 3.14%[14]

Heating_Consumption = Estimate of annual household heating consumption

	Gas_Heating_Consumption (MMBtu)	
	Existing Homes[19]	**New Construction**[20]
Gas	81	67
Oil	84	70
Unknown	82	67

Heating_Reduction = Assumed percentage reduction in total household heating energy consumption due to advanced thermostat

Program	**Existing Thermostat Type**	**Heating_Reduction**[15]
Existing Homes	Unknown (Blended)	7.7%
New Construction	Programmable	5.6%

SEER = the cooling equipment's Seasonal Energy Efficiency Ratio rating (kBtu/kWh)

SEER	
Existing Homes	**New Construction**
13.2[10]	15.0[16]

Load Shapes

5b Residential Space heat
120d Advanced Thermostat - Fossil Heat & Cooling
122d Advanced Thermostat - Unknown Heat & Cooling
121d Advanced Thermostat - Electric Heat & Cooling

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
5	Residential Space heat	Active	42.9 %	57.1 %	0.0 %	0.0 %	25.0 %	0.0 %
120	Advanced Thermostat - Fossil Heat & Cooling	Active	14.1 %	14.9 %	40.5 %	30.5 %	2.8 %	16.0 %
122	Advanced Thermostat - Unknown Heat & Cooling	Active	35.6 %	46.5 %	10.2 %	7.7 %	25.0 %	9.3 %
121	Advanced Thermostat - Electric Heat & Cooling	Active	36.5 %	47.8 %	9.0 %	6.7 %	25.0 %	8.0 %

Net Savings Factors

Measures

SHESMART	Advanced Thermostats

Tracks [Base Track]

6032EPEP [is base track]	Efficient Products - Residential

Lifetimes

The expected measure life for advanced thermostats is assumed to be similar to that of a programmable thermostat 10 years[21] based upon equipment life only.

Measure Cost

For DI and other programs for which installation services are provided, the actual material, labor, and other costs should be used, with a default of $265 ($225 for the thermostat and $40 for labor). For retail, Bring Your Own Thermostat (BYOT) programs[22], or other program types the average incremental cost for the new installation measure is assumed to be $175[23].

For new construction, the incremental cost between a programmable and advanced thermostat is assumed to be $150[24].

Prescriptive Savings Tables

Deemed savings are provided below*[3734]*.

Savings Type	Fuel	Existing Homes*[3735]*							
		Natural Gas Heat, Cooling	Natural Gas Heat, No Cooling	Oil Heat, Cooling	Oil Heat, No Cooling	LP Heat, Cooling	LP Heat, No Cooling	HP Heat, Cooling	Unknown Heat (not NG), Unknown Cooling
Heating	Natural Gas (MMBTU)	4.3	4.3	0.0	0.0	0.0	0.0	0.0	0.0
Heating	Oil (MMBTU)	0.0	0.0	4.5	4.5	0.0	0.0	0.0	3.4
Heating	LP (MMBTU)	0.0	0.0	0.0	0.0	4.3	4.3	0.0	1.0
Heating	Electric (kWh)	39.8	39.8	41.1	41.1	39.8	39.8	441.3	40.3
Cooling	Electric (kWh)	93.9	0.0	93.9	0.0	93.9	0.0	93.9	3.3
	Total MMBtu	4.3	4.3	4.5	4.5	4.3	4.3	0.0	4.4
	Total kWh	133.7	39.8	135.1	41.1	133.7	39.8	535.2	43.6
	kW	0.2505	0.0453	0.2505	0.0469	0.2505	0.0453	0.5026	0.0459

Savings Type	Fuel	New Construction							
		Natural Gas Heat, Cooling	Natural Gas Heat, No Cooling	Oil Heat, Cooling	Oil Heat, No Cooling	LP Heat, Cooling	LP Heat, No Cooling	HP Heat, Cooling	Unknown Heat (not NG), Unknown Cooling
Heating	Natural Gas (MMBTU)	2.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0
Heating	Oil (MMBTU)	0.0	0.0			0.0	0.0	0.0	

				2.1	2.1				0.3
Heating	LP (MMBTU)	0.0	0.0	0.0	0.0	2.0	2.0	0.0	1.7
Heating	Electric (kWh)	18.2	18.2	19	19	18.2	18.2	190.5	18.4
Cooling	Electric (kWh)	82.6	0.0	82.6	0.0	82.6	0.0	82.6	6.8
	Total MMBtu	2.0	2.0	2.1	2.1	2.0	2.0	0.0	2.0
	Total kWh	100.8	18.2	101.6	19.0	100.8	18.2	273.1	25.2
	kW	0.2202	0.0213	0.2202	0.0222	0.2202	0.0213	0.2228	0.0215

Footnotes

[1] For example, the capabilities of products and added services that use ultrasound, infrared, or geofencing sensor systems, automatically develop individual models of home's thermal properties through user interaction, and optimize system operation based on equipment type and performance traits based on weather forecasts demonstrate the type of automatic schedule change functionality that apply to this measure characterization.

[2] This measure recognizes that field data may be available, through this 2-way communication capability, to better inform characterization of efficiency criteria and savings calculations. Efficiency Vermont will be exploring ways to better utilize this data once the program is underway and once the ENERGY STAR specification and program process is finalized.

[3] EVT applied 25% adjustment factor to U.S. Climate Cooling Region 2 Full Load Hours of 500 hours for 375 hours.

[4] Estimated by following a methodology outlined in the Uniform Methods Project using natural gas billing data provided by Vermont Gas Systems (VGS) for homes that participated in Efficiency Vermont's Residential New Construction (RNC) program. Since capacity has not been collected through the Home Performance with ENERGY STAR program it was not possible to perform the analysis with a more appropriate data set for this program. For Existing Homes, the RNC data was limited to only those homes with annual gas consumption greater than 25kBtu/sq ft in an attempt to remove the high performance/ low load homes in RNC. See 'VGS Usage Regression Work_04182017.xls' for analysis.

[5] Vermont Single-Family Existing Homes Onsite Report, 2/15/2013, Tables 5-18 Characteristics of Air Conditioning Systems, Statewide. Includes Central AC, Ground Source Heat Pump and estimates that 50% of ductless minisplits could be controlled by advanced thermostats. Room AC is excluded as this will not be controlled.

[6] Section 6, Vermont Residential New Construction Baseline Study Analysis of On-Site Audits, 2/13/2013. Eight out of 97 homes had central air coniditioning units.

[7] Based on review of # of thermostats per home data from Vermont Single-Family Existing Homes Onsite Report, 2/15/2013 and Vermont Residential New Construction Baseline Study Analysis of On-Site Audits, 2/13/2013. See 'Advanced Thermostat Analysis_04182017_FINAL.xls'

[8] Unknown value is based on TAG agreement 2017.

[9] Unknown value is based onTAG agreement 2017.

[10] TAG Agreement 2017.

[11] This assumption is based upon the review of many evaluations from other regions in the US (see "Studies informing the TRM Savings Characterization for Advanced Thermostats.docx"). These sources, are from different regions, products, and program delivery designs, but collectively form a sound basis, and directional guidance for the existence and magnitude of cooling savings. Because cooling savings are more volatile than those for heating due to variables in control behaviors, population, and product factors, conservatism is warranted and 8% is considered a conservative estimate based upon the array of results from these studies. Further evaluation and regular review of this key assumption is encouraged.

[12] Estimate is based upon calculation of average heating load from Vermont Single-Family Existing Homes Onsite Report, 2/15/2013. This is converted to kWh using relative efficiencies, and an assumption that 90% of heat pump load is delivered in heat pump mode v resistance. See "Advanced Thermostat Analysis_04182017_FINAL.xlsx", for details.

[13] Estimate is based upon calculation of average heating load from Vermont Residential New Construction Baseline Study Analysis of On-Site Audits, 2/13/2013. This is converted to kWh using relative efficiencies, and an assumption that 90% of heat pump load is delivered in heat pump mode v resistance. See "Advanced Thermostat Analysis_04182017_FINAL.xlsx", for details.

[14] F_e is not one of the AHRI certified ratings provided for residential furnaces, but can be reasonably estimated from a calculation based on the certified values for fuel energy (Ef in MMBTU/yr) and Eae (kWh/yr). An average of a 300 record sample (non-random) out of 1495 was 3.14%. This is, appropriately, ~50% greater than the Energy Star version 3 criteria for 2% F_e. See "Programmable Thermostats Furnace Fan Analysis.xlsx" for reference. Note this is a reasonable estimate for a boilers electric consumption which is a similar level to furnaces as per Table 10.1, page 30 of James Lutz et al., Lawrence Berkeley Laboratory "Modeling energy consumption of residential furnaces and boilers in US homes" (http://eetd.lbl.gov/sites/all/files/modeling_energy_consumption_of_residential_furnaces_and_boilers_in_us_homes_lbnl-53924.pdf).

[15] Savings of 8.8% for manual, and 5.6% for programmable thermostats as presented in Navigant's PowerPoint on Impact Analysis from Preliminary Gas savings findings (slide 28 of 'IL SAG Smart Thermostat Preliminary Gas Impact Findings 2015-12-08 to IL SAG.ppt'). These values are used as the basis for the weighted average savings value for existing homes. The weighting of manual to programmable thermostats for when unknown is based upon Vermont Single-Family Existing Homes Onsite Report, 2/15/2013, 'Table 5-13 Type of Thermostat'.

[16] TAG Agreement 2017.

[17] Vermont Single-Family Existing Homes Onsite Report, 2/15/2013, Table5-1 using ACS data, percent of homes that are not natural gas, wood or

other.

[18] Vermont Residential New Construction Baseline Study Analysis of On-Site Audits, 2/13/2013, Table 5-1. Percent of homes that are not natural gas, wood or other.

[19] Estimate is based upon calculation of average heating load; (FLH * Capacity/1,000,000)/AFUE. FLH and Capacity are based upon natural gas billing data anaylsis provided by Vermont Gas Systems (VGS) (see 'VGS Usage Regression Work_04182017.xls'). AFUE assumptions are from Vermont Single-Family Existing Homes Onsite Report, 2/15/2013. Note the FLH calculation attempts to isolate heating only consumption (removing DHW and other loads). For calculation of savings see "Advanced Thermostat Analysis_04182017_FINAL.xlsx", for details.

[20] Estimate is based upon calculation of average heating load; (FLH * Capacity/1,000,000)/AFUE. FLH and Capacity are based upon natural gas billing data anaylsis provided by Vermont Gas Systems (VGS) (see 'VGS Usage Regression Work_04182017.xls'). AFUE assumptions are from Vermont Residential New Construction Baseline Study Analysis of On-Site Audits, 2/13/2013. Note the FLH calculation attempts to isolate heating only consumption (removing DHW and other loads). For calculation of savings see "Advanced Thermostat Analysis_04182017_FINAL.xlsx", for details.

[21] Table 1, HVAC Controls, Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, 2007

[22] In contrast to program designs that utilize program affiliated contractors or other trade ally partners that support customer participation through thermostat distribution, installation and other services, BYOT programs enroll customers *after* the time of purchase through online rebate and program integration sign-ups.

[23] Market prices vary considerably in this category, generally increasing with thermostat capability and sophistication. The core suite of functions required by this measure's eligibility criteria are available on units readily available in the market roughly in the range of $200 and $250, excluding the availability of any wholesale or volume discounts. The assumed incremental cost is based on the middle of this range ($225) minus a cost of $50 for the baseline equipment blend of manual and programmable thermostats. Note that any add-on energy service costs, which may include one-time setup and/or annual per device costs are not included in this assumption.

[24] Assumed to be $225 minus $75 for programmable thermostat.

Advanced Thermostat Optimization Services

Measure Number: **IV-J-3 b**
Portfolio: EVT TRM Portfolio 2018-05
Status: Inactive
Effective Date: 2018/1/1
End Date: 2018/12/31
Program: Efficient Products Program
End Use: HVAC

Update Summary

Added weighted average assumptions (for summer seasonal and winter seasonal programs - and for gas heated homes and non-gas heated homes) based on fuel mix from programmable thermostat sales October 2017 through March 2018. This is because current implementation method does not provide information on home type (new v existing) or heating fuel.

Referenced Documents

- VGS Usage Regression Work_04182017
- Nest_seasonal_savings_white_paper
- Nest_SeasonalSavings_Impacts_Winter1617_VEIC
- dcseu-seasonal-savings-proposal-updated-pdf
- EVT_AdvThermostatOptimized v3

Description

This measure provides the characterization of *additional* savings to the Advanced Thermostat measure which are achieved for participants enrolling in add-on optimization services which are designed to enhance the savings from their existing advanced thermostat. Software add ons deploy set point altering algorithms to generate additional heating and cooling savings than would be realized from just the advanced thermostat alone. Details of the participants enrolling together with an end of year report detailing those participants and the impacts on setback resulting from the software will be provided to Efficiency Vermont for future measure refinement.

Baseline Efficiencies

The baseline is a customer with an advanced thermostat that has not enrolled on an additional optimization program.

Efficient Equipment

The efficient case is a participant that has enrolled on an optimization program.

Algorithms

Electric Demand Savings

$$\Delta kW = \mathrm{Max}(\Delta kWh_{CoolingOptimized} / EFLH_{Cool}, \Delta kWh_{HeatingOptimized} / EFLH_{Heat})$$

Symbol Table

Electric Energy Savings

$$\Delta kWh = \Delta kWh_{CoolingOptimized} + \Delta kWh_{HeatingOptimized}$$

$$\Delta kWh_{CoolingOptimized} = NewCoolingConsumption \times Cooling_{OptimizedlReduction}$$

$$\Delta kWh_{HeatingOptimized} = NewElecHeatingConsumption \times Heating_{OptimizedReduction}$$

Symbol Table

Fossil Fuel Savings

$$\Delta MMBtu = NewFuelHeatingConsumption \times Heating_{OptimizedReduction}$$

Where:

ΔkW = Gross customer connected load kW savings for the measure.

$\Delta kWh_{CoolingOptimized}$ = Additional cooling savings from participants enrolled in Optimization program.

$\Delta kWh_{HeatingOptimized}$ = Additional heating savings from participants enrolled in Optimization program.

ΔkWh = Gross customer annual kWh savings for the measure

ΔMMBtu = Gross customer annual MMBtu fuel savings for the measure

$\text{Cooling}_{\text{OptimizedlReduction}}$ = Assumed percentage reduction in household cooling energy consumption due to Nest Seasonal Savings.

= 3.5%[3]

$\text{EFLH}_{\text{Cool}}$ = Estimate of annual household full load cooling hours for air conditioning equipment.

= 375[1]

$\text{EFLH}_{\text{Heat}}$ = Assumed Equivalent Full Load Hours for heating

EFLH[2]	
Existing Homes	**New Construction**
878	855

$\text{Heating}_{\text{OptimizedReduction}}$ = Assumed percentage reduction in household heating energy consumption due to Optimized add on.

= 3.5%

NewCoolingConsumption = New cooling consumption - i.e. calculation of consumption after subtracting the base level savings from the Advanced Thermostat measure. See 'EVTOptimizedSavings.xls' for more information.

NewElecHeatingConsumption = New heating consumption - i.e. calculation of consumption after subtracting the base level savings from the Advanecd Thermostat measure. See 'EVT_AdvThermostatOptimized.xls' for more information.

NewFuelHeatingConsumption = New heating consumption - i.e. calculation of consumption after subtracting the base level savings from the Advanced Thermostat measure. See 'EVT_AdvThermostatOptimized.xls' for more information.

Load Shapes

11a Residential A/C
5b Residential Space heat
120d Advanced Thermostat - Fossil Heat & Cooling
122d Advanced Thermostat - Unknown Heat & Cooling
121d Advanced Thermostat - Electric Heat & Cooling

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
11	Residential A/C	Active	0.7 %	2.8 %	53.3 %	43.2 %	0.0 %	82.9 %
5	Residential Space heat	Active	42.9 %	57.1 %	0.0 %	0.0 %	25.0 %	0.0 %
120	Advanced Thermostat - Fossil Heat & Cooling	Active	14.1 %	14.9 %	40.5 %	30.5 %	2.8 %	16.0 %
122	Advanced Thermostat - Unknown Heat & Cooling	Active	35.6 %	46.5 %	10.2 %	7.7 %	25.0 %	9.3 %
121	Advanced Thermostat - Electric Heat & Cooling	Active	36.5 %	47.8 %	9.0 %	6.7 %	25.0 %	8.0 %

Net Savings Factors

Measures

SHESMART	Advanced Thermostats

Tracks [Base Track]

6032EPEP [is base track]	Efficient Products - Residential

Lifetimes

The expected measure life for savings associated with the Nest Seasonal Savings program is 1 year.

Measure Cost

The cost to enroll is $6.00 per participant for a single year[4]

Prescriptive Savings Tables

Deemed savings are provided below. The first two tables provide default savings for when implementation does not allow the building or heating type to be known.[5]

Summer Seasonal Program:

Savings Type	Fuel	Weighted Average
Cooling	Electric (kWh)	24.9
Loadshape	kW	0.0664
	11a Residential AC	

Winter Seasonal Program:

Savings Type	Fuel	Weighted Average		
		Natural Gas	Non Natural Gas	HP Electric Heat
Heating	Natural Gas (MMBTU)	1.8	0.0	0.0
Heating	Oil (MMBTU)	0.0	1.0	0.0
Heating	LP (MMBTU)	0.0	0.7	0.0
Heating	Electric (kWh)	16.5	23.9	181.9
	Total MMBTU	1.8	1.7	0.0
	Total kWh	16.5	23.9	181.9
	kW	0.0188	0.0272	0.2071
	Loadshape	5a Residential Space heat		

Savings Type	Fuel	Existing Homes							
		Natural Gas Heat, Cooling	Natural Gas Heat, No Cooling	Oil Heat, Cooling	Oil Heat, No Cooling	LP Heat, Cooling	LP Heat, No Cooling	HP Heat, Cooling	Unknown Heat (not NG), Unknown Cooling
Heating	Natural Gas (MMBTU)	1.8	1.8	0.0	0.0	0.0	0.0	0.0	0.0
Heating	Oil (MMBTU)	0.0	0.0	1.9	1.9	0.0	0.0	0.0	1.1
Heating	LP (MMBTU)	0.0	0.0	0.0	0.0	1.8	1.8	0.0	0.3
Heating	Electric (kWh)	16.6	16.6	17.2	17.2	16.6	16.6	184.0	12.6
Cooling	Electric (kWh)	25.0	0.0	25.0	0.0	25.0	0.0	25.0	0.9
	Total MMBTU	1.8	1.8	1.9	1.9	1.8	1.8	0.0	1.4
	Total kWh	41.6	16.6	42.2	17.2	41.6	16.6	209.0	13.5
	kW	0.0667	0.0189	0.0667	0.0195	0.0667	0.0189	0.2096	0.0144
	Loadshape Used	120b Advanced Thermostat - Fossil Heat & Cooling	5a Residential Space heat	120b Advanced Thermostat - Fossil Heat & Cooling	5a Residential Space heat	120b Advanced Thermostat - Fossil Heat & Cooling	5a Residential Space heat	121b Advanced Thermostat - Electric Heat & Cooling	122b Advanced Thermostat - Unknown Heat & Cooling

Savings Type	Fuel	Residential New Construction							
		Natural Gas Heat, Cooling	Natural Gas Heat, No Cooling	Oil Heat, Cooling	Oil Heat, No Cooling	LP Heat, Cooling	LP Heat, No Cooling	HP Heat, Cooling	Unknown Heat (not NG), Unknown Cooling
Heating	Natural Gas (MMBTU)	1.2	1.2	0.0	0.0	0.0	0.0	0.0	0.0
Heating	Oil (MMBTU)	0.0	0.0	1.2	1.2	0.0	0.0	0.0	0.2
Heating	LP (MMBTU)	0.0	0.0	0.0	0.0	1.2	1.2	0.0	1.0
Heating	Electric (kWh)	10.8	10.8	11.2	11.2	10.8	10.8	112.4	10.8
	Electric								

Cooling	(kWh)	16.3	0.0	16.3	0.0	16.3	0.0	16.3	1.3
	Total MMBTU	1.2	1.2	1.2	1.2	1.2	1.2	0.0	1.2
	Total kWh	27.0	10.8	27.5	11.2	27.0	10.8	128.7	12.2
	kW	0.0434	0.0126	0.0434	0.0131	0.0434	0.0126	0.1315	0.0127
	Loadshape Used	120b Advanced Thermostat - Fossil Heat & Cooling	5a Residential Space heat	120b Advanced Thermostat - Fossil Heat & Cooling	5a Residential Space heat	120b Advanced Thermostat - Fossil Heat & Cooling	5a Residential Space heat	121b Advanced Thermostat - Electric Heat & Cooling	122b Advanced Thermostat - Unknown Heat & Cooling

Footnotes

[1] EVT applied 25% adjustment factor to U.S. Climate Cooling Region 2 Full Load Hours of 500 hours for 375 hours.

[2] Estimated by following a methodology outlined in the Uniform Methods Project using natural gas billing data provided by Vermont Gas Systems (VGS) for homes that participated in Efficiency Vermont's Residential New Construction (RNC) program. Since capacity has not been collected through the Home Performance with ENERGY STAR program it was not possible to perform the analysis with a more appropriate data set for this program. For Existing Homes, the RNC data was limited to only those homes with annual gas consumption greater than 25kBtu/sq ft in an attempt to remove the high performance/ low load homes in RNC. See 'VGS Usage Regression Work_04182017.xls' for analysis.

[3] Based on findings from Nest "Seasonal Savings Impacts in Vermont", December 2016 through April 2017 (464 participating thermostats) and a deployment with over 20,000 units in Massachusetts (see attachment 1, page 12 of 'DCSEU Seasonal Savings Proposal_Updated'). The savings determined through these evaluations represent the average savings from all participants, including those that pull out or override the program.

These studies only looked at the impact on heating loads though significant cooling impacts have also been found (see 'Nest_seasonal_savings_white_paper.pdf). This measure assumes the same impact on cooling loads.

Note that through participation Efficiency Vermont will be gathering evaluation data to allow calculation of a EVT specific assumptions in the future.

[4] See attachment 1 of 'DCSEU Seasonal Savings Proposal_Updated'.

[5] See with 'EVT_AdvThermostatOptimized V2.xls' for the calculation. Note weighted average assumptions (for gas heated homes and non-gas heated homes) based on fuel mix from programmable thermostat sales October 2017 through March 2018.

ENERGY STAR Room A/C Emerging Tech Award

Measure Number:	IV-J-4 a
Portfolio:	EVT TRM Portfolio 2018-05
Status:	Active
Effective Date:	2018/1/1
End Date:	[None]
Program:	Efficient Products Program
End Use:	HVAC

Update Summary

New measure characterization for ENERGY STAR 2018 Emerging Technology Award Requirements: Room Air Conditioners with Efficient Variable Output (EVO): Outperform the CEER rating of a similar ENERGY STAR certified product without EVO by 25%.

Referenced Documents

- GDS Associates_Measure Life Report_Jun 2007
- Coincidence Factor Study Room AC PUC NH
- evt-energy-star-room-ac-analysis-august-2018

Description

This measure involves the purchase and installation of a room air conditioning unit that meets ENERGY STAR version 4.0 and outperforms the CEER without EVO[1] by 25%. This version of ENERGY STAR became is effective October 26th 2015. This is in place of a baseline unit. The baseline is based on the Federal Standard effective June 1st, 2014.

Baseline Efficiencies

The baseline assumption is a new room air conditioning unit that meets the Federal Standard (effective June 1st, 2014) efficiency standards as presented above.

Table 1: Baseline Efficiencies[2]

Product Type and Class (Btu/hr)		Federal Standard with louvered sides (CEER)	Federal Standard without louvered sides (CEER)
Without Reverse Cycle	< 8,000	11	10
	8,000 to 10,999	10.9	9.6
	11,000 to 13,999	10.9	9.5
	14,000 to 19,999	10.7	9.3
	20,000 to 27,999	9.4	9.4
	>=28,000	9	9.4
With Reverse Cycle	<14,000	9.8	9.3
	14,000 to 19,999	9.8	8.7
	>=20,000	9.3	8.7

Efficient Equipment

To qualify for this measure the new room air conditioning unit must meet the ENERGY STAR Version 4.0 plus 25% (effective October 26th 2015).

Table 2: Efficient Equipment[3]

Product Type and Class (Btu/hr)		ENERGY STAR V4.0 with louvered sides (CEER) plus 25%	ENERGY STAR V4.0 without louvered sides (CEER) plus 25%
Without Reverse Cycle	< 8,000	15.13	13.75
	8,000 to 10,999	15.00	13.25
	11,000 to 13,999	15.00	13.13
	14,000 to 19,999	14.75	12.75
	20,000 to 27,999	12.88	12.88
	>=28,000	12.38	12.88
	<14,000	13.50	12.75

With Reverse Cycle	14,000 to 19,999	13.50	12.00
	>=20,000	12.75	12.00

Algorithms

Electric Demand Savings

ΔkW $= \Delta kWh / EFLH$

Symbol Table

Electric Energy Savings

ΔkWh $= EFLH \times Btu/hr \times (1/CEER_{base} - 1/CEER_{ee}))/1000$

Where:

ΔkW = gross customer connected load kW savings for the measure

Refer to Table 5 for Demand Savings

ΔkWh = gross customer average annual kWh savings for the measure

Refer to Table 5 for Energy Savings

Btu/hr = Capacity of rebated unit (Btu/hr)

Table 3: Capacity Bins and Assumed Middle Point

Nominal Capacity Bin	Assumed Capacity
< 8,000	6,000
8,000 to 10,999	9,500
11,000 to 13,999	12,500
14,000 to 19,999	17,000
20,000 to 27,999	22,500
>=28,000	28,000
<14,000	10,000
14,000 to 19,999	17,000
>=20,000	24,000

$CEER_{base}$ = Combined Energy Efficiency Ratio of baseline unit

Refer to Table 1 for Baseline Efficiencies

$CEER_{ee}$ = Combined Energy Efficiency Ratio of ENERGY STAR unit

Refer to Table 2 for Efficient Condition Criteria

EFLH = Full Load Hours of room air conditioning unit[4]

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Load Shapes

99b Room Air Conditioning

Number	**Name**	**Status**	**Winter On kWh**	**Winter Off kWh**	**Summer On kWh**	**Summer Off kWh**	**Winter kW**	**Summer kW**
99	Room Air Conditioning	Active	0.7 %	2.8 %	53.3 %	43.2 %	0.0 %	11.9 %

Net Savings Factors

Measures

ACEESARP	Energy Star room AC

Tracks [Base Track]

6032EPEP [is base track]	Efficient Products - Residential
6038VESH [is base track]	RNC VESH

Track Name	**Track Nr.**	**Measure Code**	**Free Rider**	**Spill Over**
Efficient Products - Residential	6032EPEP	ACEESARP	0.67	1.33

RNC VESH	6038VESH	ACEESARP	1.00	1.00

Lifetimes

The assumed measure life for this measure is 12 years[5].

Measure Cost

Table 4: Incremental Costs

Capacity (Btu/hr)	Incremental Cost[6]
<6,000	$ 19.00
6,000 to 7,999	$ 27.00
8,000 to 13,999	$ 43.00
14,000 to 19,999	$ 66.00
>=20,000	$ 85.00

Savings Summary

A summary of costs and savings associated with each bin of measure can be found below[7]:

Table 5: Savings Summary

Capacity (Btu/hr)	Model	ΔkWh	ΔkW	Cost
< 8,000	Energy Star Without Reverse Cycle	22.02	0.16	$ 19.00
8,000 to 10,999	Energy Star Without Reverse Cycle	36.01	0.26	$ 43.00
11,000 to 13,999	Energy Star Without Reverse Cycle	47.72	0.34	$ 43.00
14,000 to 19,999	Energy Star Without Reverse Cycle	65.63	0.47	$ 66.00
20,000 to 27,999	Energy Star Without Reverse Cycle	91.09	0.65	$ 85.00
>=28,000	Energy Star Without Reverse Cycle	116.50	0.83	$ 85.00
<14,000	Energy Star With Reverse Cycle	40.23	0.29	$ 43.00
14,000 to 19,999	Energy Star With Reverse Cycle	71.40	0.51	$ 66.00
>=20,000	Energy Star With Reverse Cycle	102.71	0.73	$ 85.00

Footnotes

[1] Efficient Variable Output

[2] Federal Standard effective June 1, 2014. Section 430.32 Title 10: Energy Subpart C—Energy and Water Conservation Standards. https://www.ecfr.gov/cgi-bin/text-idx?rgn=div8&node=10:3.0.1.4.18.3.9.2

[3] https://www.energystar.gov/sites/default/files/asset/document/ENERGY%20STAR%202018%20Emerging%20Technology%20Award%20Criteria%20Requirements%20-%20Room%20Air%20Conditioners%20with%20Efficient%20Variable%20Output.pdf

[4] Equivalent full load hours for Burlington, VT from RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008 (http://www.puc.nh.gov/Electric/Monitoring%20and%20Evaluation%20Reports/National%20Grid/117_RLW_CF%20Res%20RAC.pdf)

[5] Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures, GDS Associates, June 2007

[6] Costs are averaged from vendor pricing for typical models meeting these criteria.

[7] Analysis can be found in EVT_ENERGY STAR Room AC_Analysis_August 2018.xlsx.

ENERGY STAR Integrated Screw Based SSL (LED) Lamps

Measure Number: IV-E-13 i
Portfolio: EVT TRM Portfolio 2018-10
Status: Inactive
Effective Date: 2018/1/1
End Date: 2018/12/31
Program: Efficient Products Program
End Use: Lighting

Update Summary

The following revisions have been made to the measure:

- Updated Loadshape #101 to account for the cooling bonus
- Removed reference to separate cooling loadshape
- Updated the footnote on loadshapes to reflect the new loadshape

Applicable Markets

Applicable Markets
Efficient Products Retail Program
Efficient Products Free
Efficient Products Hard to Reach
SMARTLIGHT
Residential Direct Install Program
LED Dropship

Referenced Documents

- Calculating Lighting and HVAC Interactions_ASHRAE
- Lighting Efficiency Waste Heat Adjustment Methodology
- Consortium for Energy Efficiency, "Residential Lighting Initiative", January 2015.
- KEMA Inc., "Impact Evaluation of the Massachusetts Upstream Lighting Program FINAL REPORT", February 2014.
- NMR, "Northeast Residential Lighting Hours-of-Use Study", 5/5/2014.
- Energy Independence and Security Act (EISA) of 2007
- US EPA, "Energy Independence and Security Act of 2007 (EISA), US EPA Backgrounder", EISA FAQ, 2011.
- ENERGY STAR Light Bulb Price Trends 2014 Q3
- NMR_Efficiency-Maine-Retail-Lighting-Program-Evaluation-Report-2015
- NMR_R154 - CT LED Lighting Study_Final Report_1
- PNNL_Analysis of Daylighting Requirements_Aug 2013
- NEEP_CI Lighting Loadshape_Jul 2011
- EVT Lighting WHF Research_Prescriptive
- EVT_ENERGY STAR LED Lamp_Analysis_Dec 2017

Description

An ENERGY STAR Integrated Screw Based SSL (LED) Lamp (specification effective October 2017) is installed in place of a baseline incandescent or halogen lamp. This measure is broken down in to Omnidirectional (e.g. A-Type lamps), Decorative (e.g. Globes and Candelabra Bulbs) and Directional (PAR Lamps, Reflectors, MR16). Further, each bulb type is broken down into Consortium for Energy Efficiency (CEE) lighting specification tiers 1 and 2[1]. For programs that track ENERGY STAR-qualified distributed bulbs but lack sufficient data to identify bulbs as either CEE Tier 1 or 2, an ENERGY STAR 2.1 'Blended' tier is provided. The blended tier is an average of the CEE tiers, weighted by EVT sales data. Note that CEE Tier 1 meets the minimum ENERGY STAR 2.1 requirements and Tier 2 exceeds this specification.

Assumptions are provided for the following markets: Efficient Products Retail, Efficient Products Free, Efficient Products Hard to Reach, SMARTLIGHT, Residential Direct Install, and Home Energy Visit ENERGY STAR LED Bulb Dropship.

Market	Description
Efficient Products Retail (Residential and Commercial)	This is for retail sales for Residential or Commercial customers.
Efficient Products Free	An LED lamp is received free of charge at an Efficiency Vermont event or as part of a targeted campaign and is installed in a Residential fixture.
Efficient Products Hard to Reach	An LED lamp is provided to those customers that have not been able to take advantage of the Retail Efficient Products program for economic, cultural or age-related reasons. These bulbs will

	be provided through VT foodbanks and other potential outlets serving disadvantaged populations
SMARTLIGHT (Residential and Commercial)	In reference to PIP #67a: Upstream Distributor Incentive Model, Efficiency Vermont offers “upstream” incentives to Vermont electrical distributors for certain eligible LED lamps.
Residential Direct Install	LED lamp is physically installed by an efficiency program representative through a direct install program
LED Dropship	An LED lamp is provided to those customers who partake in an Efficiency Vermont Home Energy Visit and are identified as having baseline lamps. LED lamps are shipped directly to customers free of charge and are installed in a Residential fixture.

Algorithms

Electric Demand Savings

$\Delta kW = ((Watts_{BASE} – Watts_{EE}) /1000) \times ISR \times WHF_d \times (1-LR)$

Symbol Table

Electric Energy Savings

$\Delta kWh = ((Watts_{BASE} – Watts_{EE}) /1000) \times ISR \times HOURS \times WHF_e \times (1-LR)$

Symbol Table

Heating Penalty

$\Delta MMBTU_{WH} = (\Delta kWh / WHF_e) \times 0.003412 \times (1 – OA) \times AR \times HF \times DFH / \eta Heat$

Where:

ΔkW = Gross customer connected load kW savings for the measure.

ΔkWh = Gross customer annual kWh savings for the measure.

$\Delta MMBTU_{WH}$ = Gross customer annual heating MMBTU fuel increased usage for the measure from the reduction in lighting heat.

$\eta Heat$ = Average heating system efficiency

= 79%[10]

0.003412 = Conversion from kWh to MMBTU

AR = Typical aspect ratio factor; the default value is 60%[11] and is based on the typical square footage of commercial building within 15 feet of exterior wall. The ASHRAE heating factor applies to perimeter zone heat, therefore it must be adjusted to account for lighting in core zones.

DFH = Percent of lighting in heated spaces, assumed to be 95%.

HF = ASHRAE heating factor of 0.39 for lighting waste heat for Burlington, Vermont for commercial lighting, assumed 0.0 for residential lighting

HOURS = Average hours of use per year.

Market	Annual Hours
Commercial Interior[7]	3,979
Residential Interior[8]	986
Residential Exterior[9]	2,044

ISR = In service rate or the percentage of units rebated that actually get used.

Dependent on **Market:**

Market	ISR
Efficient Products Retail, SMARTLIGHT, and Residential Direct Install[3]	0.97
Efficient Products Free, Efficient Products Hard to Reach, and LED Dropship[4]	0.90

LR = Leakage Rate to account for bulbs sold to customers outside of the program area

= 0.015[5] for Efficient Product Retail

= 0 for Efficient Products Free, Efficient Products Hard to Reach, SMARTLIGHT, Residential Direct Install, and Home Energy Visit ENERGY STAR LED Bulb Dropship

OA = Outside Air - the average percent of the supply air that is Outside Air, assumed to be 25%[12]

$Watts_{BASE}$ = Baseline connected kW.

$Watts_{EE}$ = Energy efficient connected kW.

WHF_d = Waste heat factor for demand to account for cooling savings from efficient lighting. For prescriptive commercial lighting in existing buildings, the default value is 1.102.[6] The cooling savings are only added to the summer peak savings. The value for residential lighting is assumed to be 1.0.

WHF_e = Waste heat factor for energy to account for cooling savings from efficient lighting. For prescriptive commercial lighting in existing buildings, the default value is 1.036.[6] The value for residential lighting is assumed to be 1.0.

Values used in algorithm and results:[2]

Market / Lamp Type		**Wattages**				**2016-2020 (Annual Savings)**		**2021 (Annual Savings)**	
		ENERGY STAR 2.1 / CEE Tier	**Base 2016-2020**	**Base 2021**	**LED**	**ΔkW**	**ΔkWh**	**ΔkW**	**ΔkWh**
Efficient Products Retail (Residential)	**Omnidirectional**	Blended	47.9	19.2	10.0	0.03625	35.7	0.00879	8.7
		CEE Tier 1	44.9	18.0	9.4	0.03399	33.5	0.00822	8.1
		CEE Tier 2	63.0	25.2	12.9	0.04778	47.1	0.01169	11.5
	Decorative	Blended	39.8	12.4	4.7	0.03360	33.1	0.00745	7.3
		CEE Tier 1	39.1	12.3	5.0	0.03258	32.1	0.00699	6.9
		CEE Tier 2	40.6	12.6	4.3	0.03467	34.2	0.00793	7.8
	Directional	Blended	70.2	20.3	9.7	0.05779	57.0	0.01012	10.0
		CEE Tier 1	68.2	19.7	9.5	0.05614	55.3	0.00979	9.6
		CEE Tier 2	80.7	23.3	10.9	0.06672	65.8	0.01189	11.7
SMARTLIGHT (Residential) and Residential Direct Install (Interior)	**Omnidirectional**	Blended	47.9	19.2	10.0	0.03680	36.3	0.00893	8.8
		CEE Tier 1	44.9	18.0	9.4	0.03451	34.0	0.00835	8.2
		CEE Tier 2	63.0	25.2	12.9	0.04851	47.8	0.01187	11.7
	Decorative	Blended	39.8	12.4	4.7	0.03411	33.6	0.00756	7.5
		CEE Tier 1	39.1	12.3	5.0	0.03307	32.6	0.00710	7.0
		CEE Tier 2	40.6	12.6	4.3	0.03520	34.7	0.00805	7.9
	Directional	Blended	70.2	20.3	9.7	0.05867	57.8	0.01027	10.1
		CEE Tier 1	68.2	19.7	9.5	0.05699	56.2	0.00994	9.8
		CEE Tier 2	80.7	23.3	10.9	0.06773	66.8	0.01207	11.9
Efficient Products Retail (Commercial)	**Omnidirectional**	Blended	47.9	19.2	10.0	0.03995	149.4	0.00969	36.2
		CEE Tier 1	44.9	18.0	9.4	0.03746	140.1	0.00906	33.9
		CEE Tier 2	63.0	25.2	12.9	0.05265	197.0	0.01288	48.2
	Decorative	Blended	39.8	12.4	4.7	0.03702	138.5	0.00821	30.7
		CEE Tier 1	39.1	12.3	5.0	0.03590	134.3	0.00770	28.8
		CEE Tier 2	40.6	12.6	4.3	0.03821	142.9	0.00874	32.7
	Directional	Blended	70.2	20.3	9.7	0.06369	238.2	0.01115	41.7
		CEE Tier 1	68.2	19.7	9.5	0.06186	231.4	0.01079	40.3
		CEE Tier 2	80.7	23.3	10.9	0.07352	275.0	0.01311	49.0
SMARTLIGHT (Commercial)	**Omnidirectional**	Blended	47.9	19.2	10.0	0.04056	151.7	0.00984	36.8
		CEE Tier 1	44.9	18.0	9.4	0.03803	142.3	0.00920	34.4
		CEE Tier 2	63.0	25.2	12.9	0.05346	200.0	0.01308	48.9
	Decorative	Blended	39.8	12.4	4.7	0.03759	140.6	0.00833	31.2
		CEE Tier 1	39.1	12.3	5.0	0.03645	136.3	0.00782	29.2
		CEE Tier 2	40.6	12.6	4.3	0.03879	145.1	0.00887	33.2
	Directional	Blended	70.2	20.3	9.7	0.06466	241.9	0.01132	42.3
		CEE Tier 1	68.2	19.7	9.5	0.06281	234.9	0.01095	41.0

		CEE Tier 2	80.7	23.3	10.9	0.07464	279.2	0.01331	49.8
Efficient Products Free, Efficient Products Hard to Reach, and LED Dropship	**Omnidirectional**	Blended	47.9	19.2	10.0	0.03415	33.7	0.00828	8.2
		CEE Tier 1	44.9	18.0	9.4	0.03202	31.6	0.00775	7.6
		CEE Tier 2	63.0	25.2	12.9	0.04501	44.4	0.01101	10.9
	Decorative	Blended	39.8	12.4	4.7	0.03165	31.2	0.00701	6.9
		CEE Tier 1	39.1	12.3	5.0	0.03069	30.2	0.00658	6.5
		CEE Tier 2	40.6	12.6	4.3	0.03266	32.2	0.00747	7.4
	Directional	Blended	70.2	20.3	9.7	0.05444	53.6	0.00953	9.4
		CEE Tier 1	68.2	19.7	9.5	0.05288	52.1	0.00922	9.1
		CEE Tier 2	80.7	23.3	10.9	0.06285	61.9	0.01120	11.0
Residential Direct Install Exterior	**Omnidirectional**	Blended	47.9	19.2	10.0	0.03680	75.2	0.00893	18.2
		CEE Tier 1	44.9	18.0	9.4	0.03451	70.5	0.00835	17.1
		CEE Tier 2	63.0	25.2	12.9	0.04851	99.1	0.01187	24.3
	Decorative	Blended	39.8	12.4	4.7	0.03411	69.7	0.00756	15.5
		CEE Tier 1	39.1	12.3	5.0	0.03307	67.6	0.00710	14.5
		CEE Tier 2	40.6	12.6	4.3	0.03520	71.9	0.00805	16.5
	Directional	Blended	70.2	20.3	9.7	0.05867	119.9	0.01027	21.0
		CEE Tier 1	68.2	19.7	9.5	0.05699	116.5	0.00994	20.3
		CEE Tier 2	80.7	23.3	10.9	0.06773	138.4	0.01207	24.7

Using default values, the MMBtu penalties for each commercial bulb type are provided below. Penalty values are not provided for residential markets because Efficiency Vermont does not calculate interactive effects for residential lighting.Oil heating is assumed typical for commercial buildings.

Market/Lamp Type		**ENERGY STAR 2.1 / CEE Tier**	**$\Delta MMBTU_{WH}$**	
			2016-2020	**2021**
Efficient Products Retail (Commercial)	**Omnidirectional**	Blended	0.104	0.025
		CEE Tier 1	0.097	0.024
		CEE Tier 2	0.137	0.033
	Decorative	Blended	0.096	0.021
		CEE Tier 1	0.093	0.020
		CEE Tier 2	0.099	0.023
	Directional	Blended	0.166	0.029
		CEE Tier 1	0.161	0.028
		CEE Tier 2	0.191	0.034
SMARTLIGHT (Commercial)	**Omnidirectional**	Blended	0.105	0.026
		CEE Tier 1	0.099	0.024
		CEE Tier 2	0.139	0.034
	Decorative	Blended	0.098	0.022
		CEE Tier 1	0.095	0.020
		CEE Tier 2	0.101	0.023
	Directional	Blended	0.168	0.029
		CEE Tier 1	0.163	0.028
		CEE Tier 2	0.194	0.035

Baseline Efficiencies

Federal legislation stemming from the Energy Independence and Security Act of 2007 began the phasing out of omnidirectional incandescent bulbs. From 2012, 100W incandescents could no longer be manufactured, followed by restrictions on 75W in 2013 and 60W/40W in 2014. The baseline for this measure has become EISA compliant incandescent and halogen bulbs. Currently, all directional bulbs are exempt from active EISA requirements and the incandescent equivalent is used for this baseline. Decorative bulbs less than or equal to 40 watts are also exempt from current EISA requirements. The decorative bulb baseline is a weighted average of those bulbs impacted by EISA and those that are exempt.

Due to recent legislation, the definitions of General Service Lamps (GSLs) have been redefined and will become effective January 1, 2020. At this time, the efficacy exemptions on these bulb types are expected to be discontinued and all bulb types evaluated in this measure will be subject to the EISA requirement of 45 lumens per watt efficacy. In recognition of the likely reality that significant volumes of lower performing products will remain in the market beyond 2020, that there will be no or minimal enforcement, and the political uncertainty surrounding upcoming efficiency regulations, EVT will model the shift to a baseline of 45 lumens per watt starting in 2021.

High Efficiency

The high efficiency wattage is assumed to be a CEE Tier 1 or Tier 2 qualified lamp. ENERGY STAR 'Blended' values should be used if the CEE Tier is unknown. See EVT_ENERGY STAR LED Lamp_Analysis_Dec 2017.xlsx for details.

Baseline Adjustment

To account for EISA requirements, the future savings for this measure should be reduced to account for the higher baselines in 2021. The following table shows the calculated baselines for all bulb types for years 2016-2020 and the adjsutment in 2021[2]:

Lamp Type	ENERGY STAR 2.1 / CEE Tier	LED (Watts)	Bulb Wattages Assumed in Calculation		2021 Savings Adjustment Factor
			Base 2016-2020 (Watts)	Base 2021 (Watts)	
Omnidirectional	Blended	10.0	47.9	19.2	24.3%
	CEE Tier 1	9.4	44.9	18.0	24.2%
	CEE Tier 2	12.9	63.0	25.2	24.5%
Decorative	Blended	4.7	39.8	12.4	22.2%
	CEE Tier 1	5.0	39.1	12.3	21.5%
	CEE Tier 2	4.3	40.6	12.6	22.9%
Directional	Blended	9.7	70.2	20.3	17.5%
	CEE Tier 1	9.5	68.2	19.7	17.4%
	CEE Tier 2	10.9	80.7	23.3	17.8%

Averages weighted on ENERGY STAR 2.1 qualifed products from EVT Efficient Product sales data (Jan-Sept 2017)

Operating Hours

See Algorithm Section above.

Load Shapes

Residential: Loadshape #1: Residential Indoor Lighting

Commercial: Loadshape #101: Commercial EP Lighting with Cooling Bonus[13]

1a Residential Indoor Lighting
101c Commercial EP Lighting with cooling bonus

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
1	Residential Indoor Lighting	Active	36.9 %	35.0 %	13.0 %	15.1 %	29.8 %	8.2 %
101	Commercial EP Lighting with cooling bonus	Active	47.7 %	19.2 %	23.0 %	10.1 %	33.8 %	68.1 %

Net Savings Factors

Measures

LBLLEDSC	ENERGY STAR Integrated Screw Based SSL (LED) Lamps

Tracks [Base Track]

6013UPST [is base track]	Upstream - Commercial
6032EPEP [is base track]	Efficient Products - Residential
6034LISF [is base track]	LISF Retrofit
6036RETR [is base track]	Res Retrofit
6038VESH [is base track]	RNC VESH

Persistence

The persistence factor is assumed to be one.

Lifetimes

Lifetime is a function of the average hours of use of the luminaire.

Lamp Type	ENERGY STAR 2.1 / CEE Tier	Rated Life (Hours)	Residential Interior (Years)	Residential Exterior (Years)	Commercial (Years)
Omnidirectional	Blended	21,764	15.0	10.6	5.5
	CEE Tier 1	20,696	15.0	10.1	5.2
	CEE Tier 2	25,073	15.0	12.3	6.3
Decorative	Blended	20,494	15.0	10.0	5.2
	CEE Tier 1	21,124	15.0	10.3	5.3
	CEE Tier 2	19,414	15.0	9.5	4.9
Directional	Blended	25,299	15.0	12.4	6.4
	CEE Tier 1	25,126	15.0	12.3	6.3
	CEE Tier 2	25,457	15.0	12.5	6.4

'Rated life' based on CEE Tier/ENERGY STAR 2.1 qualfying product average-rated-life weighted by EVT Efficient Products sales data.Note all lifetimes are capped at 15 years (although their rated life/hours may be higher).

Measure Cost

For Efficient Products and SMARTLIGHT, the efficient, baseline, and incremental costs for these measures are provided below:[14]

Lamp Type	ENERGY STAR 2.1 / CEE Tier	Lamp Costs		Incremental Cost
		LED	Baseline	
Omnidirectional	Blended	$10.93	$1.50	$9.43
	CEE Tier 1	$10.06	$1.50	$8.56
	CEE Tier 2	$15.36	$1.50	$13.86
Decorative	Blended	$15.43	$1.00	$14.43
	CEE Tier 1	$14.92	$1.00	$13.92
	CEE Tier 2	$15.54	$1.00	$14.54
Directional	Blended	$17.16	$5.00	$12.16
	CEE Tier 1	$16.81	$5.00	$11.81
	CEE Tier 2	$19.23	$5.00	$14.23

For Direct Install the full lamp cost plus labor is provided below:

Lamp Type	ENERGY STAR 2.1 / CEE Tier	LED Lamp Cost	Labor Cost	Total Measure Cost[15]
Omnidirectional	Blended	$10.93	$2.67	$13.60
	CEE Tier 1	$10.06	$2.67	$12.73
	CEE Tier 2	$15.36	$2.67	$18.03
Decorative	Blended	$15.43	$2.67	$18.10
	CEE Tier 1	$14.92	$2.67	$17.59
	CEE Tier 2	$15.54	$2.67	$18.21
Directional	Blended	$17.16	$2.67	$19.83
	CEE Tier 1	$16.81	$2.67	$19.48
	CEE Tier 2	$19.23	$2.67	$21.90

O&M Cost Adjustments

To account for the shift in baseline due to the Federal Legislation, the levelized baseline replacement cost over the lifetime of the LED is calculated.[2] The key assumptions used in this calculation are documented below:

Lamp Type	Assumptions	Base 2016-2020	Base 2021
Omnidirectional	Replacement Cost	$1.50	$2.50
	Component Life (hours)	1,000	10,000
Decorative	Replacement Cost	$1.00	$5.00
	Component Life (hours)	1,000	10,000
Directional	Replacement Cost	$5.00	$8.50
	Component Life (hours)	1,000	10,000

The calculation results in the following assumptions of equivalent annual baseline replacement cost:

Market / Lamp Type		**ENERGY STAR 2.1 / CEE Tier**	**Annual baseline O&M assumption for bulbs installed in**		
			2018	**2019**	**2020**
Efficient Products Residential, Direct Install Interior, and LED Dropship	**Omnidirectional**	Blended	$0.51	$0.42	$0.32
		CEE Tier 1	$0.51	$0.42	$0.32
		CEE Tier 2	$0.51	$0.42	$0.32
	Decorative	Blended	$0.59	$0.55	$0.51
		CEE Tier 1	$0.59	$0.55	$0.51
		CEE Tier 2	$0.59	$0.55	$0.51
	Directional	Blended	$1.82	$1.50	$1.16
		CEE Tier 1	$1.82	$1.50	$1.16
		CEE Tier 2	$1.82	$1.50	$1.16
Residential Direct Install Exterior	**Omnidirectional**	Blended	$0.60	$0.48	$0.34
		CEE Tier 1	$0.61	$0.47	$0.34
		CEE Tier 2	$0.55	$0.44	$0.32
	Decorative	Blended	$0.62	$0.56	$0.51
		CEE Tier 1	$0.60	$0.55	$0.49
		CEE Tier 2	$0.65	$0.59	$0.53
	Directional	Blended	$1.96	$1.58	$1.19
		CEE Tier 1	$1.97	$1.59	$1.20
		CEE Tier 2	$1.99	$1.61	$1.23
Commercial	**Omnidirectional**	Blended	$6.92	$5.98	$5.01
		CEE Tier 1	$6.58	$5.60	$4.58
		CEE Tier 2	$6.08	$5.25	$4.40
	Decorative	Blended	$5.79	$5.40	$4.99
		CEE Tier 1	$5.63	$5.25	$4.85
		CEE Tier 2	$6.09	$5.67	$5.24
	Directional	Blended	$14.16	$11.44	$8.63
		CEE Tier 1	$14.25	$11.51	$8.68
		CEE Tier 2	$14.08	$11.37	$8.58

Fossil Fuel Description

See Heating Increased Usage above.

Water Descriptions

There are no water algorithms or default values for this measure.

Footnotes

[1] Consortium for Energy Efficiency, "Residential Lighting Initiative", January 2015. Page 25, Table A.1

[2] For details on calculations, see reference file EVT_ENERGY STAR LED Lamp_Analysis_Dec 2017.xlsx.

[3] Lifetime ISR for Efficient Products Retail and SMARTLIGHT based on methodology from Chapter 21: Residential Lighting Evaluation Protocol of the Uniform Methods Project. Using a 1st Year ISR of 92.5% (average of 1st year ISR of 90% from NMR Group, Inc., "Efficiency Maine Retail Lighting Program Overall Evaluation Report FINAL," 4/16/2015. Page 14, Table 2-1 and 95% from NMR Group, Inc., "Connecticut LED Lighting Study Report (R154) FINAL," 1/28/2016. Page V, Table 1) and a discount rate of 3.00% based on the Vermont societal cost test, the lifetime ISR after three years is 97%. See file EVT_ENERGY STAR LED Lamp_Analysis_Dec 2017.xlsx for calculaton details. ISR for Residential Direct Install based on Illinois Technical Reference Manual for Energy Efficiency, Version 6.0, which accounts for bulb failures during the first year

[4] Lifetime ISR for Efficient Products Free, Hard to Reach, and LED Dropship based on methodology from Chapter 21: Residential Lighting Evaluation Protocol of the Uniform Methods Project. Using a 1st Year ISR of 70% (1st year ISR value for both CFL and LED bulbs in efficiency kits is 59% in the Illinois Technical Reference Manual for Energy Efficiency, Version 6.0 ("Free bulbs provided without request, with little or no education. Based on 'Impact and Process Evaluation of 2013 (PY6) Ameren Illinois Company Residential CFL Distribution Program', Report Table 11 and Appendix B."). Efficiency Vermont assumes the ISR for free LED bulbs is higher than for free CFL bulbs.) and a discount rate of 3.00% based on the Vermont societal cost test, the lifetime ISR after three years is 90%. See file EVT_ENERGY STAR LED Lamp_Analysis_Dec 2017.xlsx for calculaton details.

[5] A leakage rate of 1.5% was agreed to by EVT and DPS during October 2017 TAG. This value is an estimate based on leakage rates used by other programs, geographic factors, and a consideration of similar lighting programs in surrounding service territories.

[6] The default waste heat factor for demand and energy is from KEMA, "NEEP C&I Lighting Loadshape Project, KEMA," 2011. The report modeled the energy savings per building type and the associated energy, demand, and coincident demand interactive effects. A description of how the interactive effects were developed is on page 28 of the report, including details about how temperature balance points, equipment efficiencies, and heat to space factors influenced each building's designated interactive effects. The building types were weighted for the NE-North Weather climate zone in order to come up with a single prescriptive default value for both demand and energy lighting waste heat factors. For more information, please see the spreadsheet, "EVT Lighting WHF Research_Prescriptive.xlsx".

[7] Commercial hours of use from Impact Evaluation of the Massachusetts Upstream Lighting Program, FINAL REPORT. KEMA Inc., "Impact Evaluation of the Massachusetts Upstream Lighting Program FINAL REPORT", February 2014. Page 1-8, Section 1.2.3.3.

[8] Based on a household average 2.7 hours of use per day. NMR, "Northeast Residential Lighting Hours-of-Use Study", 5/5/2014. Page 34, Table 3-1.

[9] Based on a household exterior average 5.6 hours of use per day. NMR, "Northeast Residential Lighting Hours-of-Use Study", 5/5/2014. Page 34, Table 3-1.

[10] Based on average efficiency for furnaces and boilers of varied sizes in ASHRAE 90.1.1999, assumed to represent typical commercial building stock in Vermont.

[11] The typical aspect ratio is sourced from PNNL, "Analysis of Daylighting Requirements within ASHRAE Standard 90.1, PNNL," 2013, from the Executive Summary on page v. The aspect ratio is sourced from 1 of 16 PNNL prototype building models. The 60% default value is from the medium office building model.

[12] 2009 ASHRAE Handbook Fundamentals (p. 16.2): "Conventional all-air air-handling systems for commercial and institutional buildings have approximately 10 to 40% outside air."

[13] Based on Commercial "Small" Lighting coincidence factors from KEMA; "C&I Lighting Load Shape Project Final Report," July 19, 2011, prepared for the Regional Evaluation, Measurement and Verification Form, submitted to NEEP. The winter coincidence factor has been adjusted to remove the cooling bonus from winter peak demand.

[14] Costs are based on 2017 EVT sales data for LED bulbs and the average retail cost averaged. See reference file EVT_ENERGY STAR LED Lamp_Analysis_Dec 2017.xlsx.

[15] Assumes labor cost to replace any kind of lamp: $2.67 per lamp (8 minutes at $20/hour)

Solid State (LED) Fixtures

Measure Number: IV-E-15 e
Portfolio: EVT TRM Portfolio 2018-10
Status: Inactive
Effective Date: 2018/1/1
End Date: 2018/12/31
Program: Efficient Products Program
End Use: Lighting

Update Summary

The measure has been revised to incorporate the revised loadshape 101c: Commercial EP Lighting with cooling bonus developed during August 2018 and agreed upon during October 2018 EVT TAG. kW and and kWh values have been corrected for Commercial Outdoor Fixtures to remove the cooling bonus. Additionally, several clarifications, primarily related to waste heat factors, have been made throughout the measure.

Applicable Markets

Applicable Markets
Efficient Products
SMARTLIGHT
Multifamily New Construction
Residential New Construction

Referenced Documents

- Calculating Lighting and HVAC Interactions_ASHRAE
- Lighting Efficiency Waste Heat Adjustment Methodology
- "Connecticut LED Lighting Study Report (R154) FINAL," prepared by NMR Group, Inc. for the Connecticut Energy Efficiency Board, January 28, 2016
- NMR Group, Inc., "Northeast Residential Lighting Hours-of-Use Study," prepared for CT Energy Efficiency Board, Cape Light Compact, Massachusetts Energy Efficiency Advisory Council, National Grid MA, National Grid RI, NYSERDA, Northeast Utilities, May 5, 2
- Rx_C&I_LED_hours
- EPA light_fixture_ceiling_fan_calculator
- UMPChapter21-residential-lighting-evaluation-protocol
- NMR_Efficiency-Maine-Retail-Lighting-Program-Evaluation-Report-2015
- PNNL_Analysis of Daylighting Requirements_Aug 2013
- NEEP_CI Lighting Loadshape_Jul 2011
- EVT Lighting WHF Research_Prescriptive
- EVT_Solid State (LED) Fixtures_Analysis_ Oct 2018

Description

An ENERGY STAR qualifying LED Fixture is purchased and installed in place of an incandescent fixture. This measure is broken into four ENERGY STAR fixture types– Indoor Fixtures (including track lighting, wall-wash, sconces, ceiling and fan lights), Task and Under Cabinet Fixtures, Outdoor Fixtures (including flood light, hanging lights, security/path lights, outdoor porch lights), and Downlight Fixtures. Assumptions are provided for the following markets: Efficient Products, SMARTLIGHT, Multifamily New Construction, and Residential New Construction.

Market	Description
Efficient Products (Residential and Commercial)	This is for retail sales for Residential or Commercial customers.
SMARTLIGHT (Residential and Commercial)	In reference to PIP #67a: Upstream Distributor Incentive Model, Efficiency Vermont offers "upstream" incentives to Vermont Electrical Distributors for certain eligible LED fixtures.
Multifamily New Construction	Fixtures installed through the Multifamily New Construction Program.
Residential New Construction	Fixtures installed through the Residential New Construction program.

Baseline Efficiencies

The 2015 Vermont RBES requires 75% of fixtures to have high efficacy lamps. For fixtures within the Multifamily New Construction and Residential New Construction programs, Efficiency Vermont will therefore assume a baseline made up of 75% high efficacy as defined by the RBES and 25% baseline lamps that are the average of EISA-equivalent wattages for ENERGY STAR-qualified products.

For all other fixtures, the baseline condition is an average of EISA-equivalent wattages for ENERGY STAR-qualified products.

Efficient Equipment

High efficiency is an ENERGY STAR-qualified LED fixture meeting the requirements in Version 2.0 of the ENERGY STAR Specification for Solid State Luminaires, effective June 1, 2016.

Algorithms

Electric Demand Savings

ΔkW	= $((Watts_{BASE} - Watts_{EE}) /1000) \times ISR \times WHF_d \times (1 - LR)$

Symbol Table

Electric Energy Savings

ΔkWh	= $((Watts_{BASE} - Watts_{EE}) /1000) \times HOURS \times ISR \times WHF_e \times (1 - LR)$

Symbol Table

Heating Increased Usage

$\Delta MMBTU_{WH}$	= $(\Delta kWh / WHF_e) \times 0.003412 \times (1 - OA) \times AR \times HF \times DFH / \eta Heat$

Where:

ΔkW	=	Gross customer connected load kW savings for the measure.
ΔkWh	=	Gross customer annual kWh savings for the measure.
$\Delta MMBTU_{WH}$	=	Gross customer annual heating MMBTU fuel increased usage for the measure from the reduction in lighting heat.
ηHeat	=	Average heating system efficiency = 79%[9]
0.003412	=	Conversion from kWh to MMBTU
AR	=	Typical aspect ratio factor. The ASHRAE heating factor applies to perimeter zone heat, therefore it must be adjusted to account for lighting in core zones. It is assumed that 60%[10] is the typical square footage of commercial buildings within 15 feet of exterior wall.
DFH	=	Percent of lighting in heated spaces. For prescriptive lighting, assumed to be 95%
HF	=	ASHRAE heating factor of 0.39 for lighting waste heat for Burlington, Vermont.[11] Assumed to be 0.0 for residential lighting and Commercial Outdoor Fixtures.
HOURS	=	Average hours of use per year.

Fixture Type	Average Annual Hours of Use	
	Residential	Commercial[5]
Indoor Fixtures	986 (Residential and Multifamily In Unit)[6] 8,760 (Indoor Hallway/Stairway or Corridor) 4,380 (Laundry)	3,667
Task/ Under Cabinet Fixtures	730[7]	2,560
Outdoor Fixtures	2,044[8]	3,960
Downlight Fixtures	986 (Residential and Multifamily In Unit)[6] 8,760 (Indoor Hallway/Stairway or Corridor) 4,380 (Laundry)	3,523

ISR	=	In service rate or the percentage of units rebated that actually get used

= 0.97[2]

LR = Leakage Rate to account for bulbs sold to customers outside of the program area

= 0.015[3] for Efficient Products

= 0 for SMARTLIGHT and New Construction

OA = Outside Air - the average percent of the supply air that is Outside Air, assumed to be 25%[12]

$Watts_{BASE}$ = Baseline connected kW

$Watts_{EE}$ = Energy efficient connected kW

Fixture Type	**Wattages[1]**				
	Efficient Products, SMARTLIGHT		**Residential and Multifamily New Construction**		**LED**
	Base 2016-2020	**Base 2021**	**Base 2016-2020**	**Base 2021**	
Indoor Fixtures	82.2	49.0	48.2	36.8	21.3
Task/ Under Cabinet Fixtures	46.9	22.9	27.2	20.6	12.8
Outdoor Fixtures	74.0	40.1	45.6	36.1	16.5
Downlight Fixtures	64.2	36.0	40.4	32.4	18.2

WHF_d = Waste heat factor for demand to account for cooling savings from efficient lighting, depending on market and fixture type.

Market	**WHF_d**
Multifamily	1.0
Residential	1.0
Commercial (except Outdoor Fixtures) [4]	1.102
Commercial Outdoor Fixtures	1.0

WHF_e = Waste heat factor for energy to account for cooling savings from efficient lighting, depending on market and fixture type.

Market	**WHF_e**
Multifamily	1.0
Residential	1.0
Commercial (except Outdoor Fixtures) [4]	1.036
Commercial Outdoor Fixtures	1.0

Using the defaults above, the kW, kWh and MMBtu savings[1] for each fixture type and market are provided below:

Market	**Fixture Type**	**Base 2016-2020**		**Base 2021**	
		ΔkW	**ΔkWh**	**ΔkW**	**ΔkWh**
Efficient Products Residential	Indoor Fixtures	0.05843	57.6	0.02658	26.2
	Task/Under Cabinet Fixtures	0.03280	23.9	0.00973	7.1
	Outdoor Fixtures	0.05522	112.9	0.02261	46.2
	Downlight Fixtures	0.04410	43.5	0.01709	16.8
	Indoor Fixtures	0.06439	222.0	0.02929	101.0
	Task/Under	0.03615	87.0	0.01073	25.8

Efficient Products Commercial	Cabinet Fixtures				
	Outdoor Fixtures	0.05522	218.7	0.02261	89.5
	Downlight Fixtures	0.04860	160.9	0.02492	62.4
SMARTLIGHT Residential	Indoor Fixtures	0.05932	58.5	0.02698	26.6
	Task/Under Cabinet Fixtures	0.03330	24.3	0.00988	7.2
	Outdoor Fixtures	0.05606	114.6	0.02295	46.9
	Downlight Fixtures	0.04477	44.1	0.01735	17.1
SMARTLIGHT Commercial	Indoor Fixtures	0.06537	225.4	0.02974	102.5
	Task/Under Cabinet Fixtures	0.03670	88.3	0.01089	26.2
	Outdoor Fixtures	0.05606	222.0	0.02295	90.9
	Downlight Fixtures	0.04934	163.4	0.01912	63.3
Multifamily New Construction	Indoor Fixtures	0.02620	25.8	0.01509	14.9
			229.5		132.2
			114.8		66.1
	Task/Under Cabinet Fixtures	0.01407	10.3	0.00764	5.6
	Outdoor Fixtures	0.02833	57.9	0.01907	39.0
	Downlight Fixtures	0.02160	21.3	0.01380	13.6
			189.2		120.9
			94.6		60.4
Residential New Construction	Indoor Fixtures	0.02620	25.8	0.01509	14.9
	Task/Under Cabinet Fixtures	0.01407	10.3	0.00764	5.6
	Outdoor Fixtures	0.02833	57.9	0.01907	39.0
	Downlight Fixtures	0.02160	21.3	0.01380	13.6

Fixture Type	**Efficient Products (Commercial)**		**SMARTLIGHT (Commercial)**	
	$\Delta MMBTU_{WH}$ - Base 2016-2020	**$\Delta MMBTU_{WH}$ - Base 2020**	**$\Delta MMBTU_{WH}$ - Base 2016-2020**	**$\Delta MMBTU_{WH}$ - Base 2020**
Indoor Fixture	0.154	0.067	0.157	0.068
Task/ Under cabinet Fixture	0.060	0.017	0.061	0.017
Outdoor Fixture	n/a	n/a	n/a	n/a
Downlight Fixtures	0.112	0.041	0.114	0.042

Baseline Adjustment

Federal legislation stemming from the Energy Independence and Security Act of 2007 began the phasing out of omnidirectional incandescent bulbs. From 2012, 100W incandescents could no longer be manufactured, followed by restrictions on 75W in 2013 and 60W/40W in 2014. The baseline for this measure has become EISA compliant incandescent and halogen bulbs. Currently, all directional bulbs are exempt from active EISA requirements and the incandescent equivalent is used for this baseline. Decorative bulbs less than or equal to 40 watts are also exempt from current EISA requirements. The decorative bulb baseline is a weighted average of those bulbs impacted by EISA and those that are exempt.

Due to recent legislation, the definitions of General Service Lamps (GSLs) have been redefined and will become effective January 1, 2020. At this time, the efficacy exemptions on these bulb types are expected to be discontinued and all bulb types evaluated in this measure will be subject to the EISA requirement of 45 lumens per watt efficacy. In recognition of the likely reality that significant volumes of lower performing products will remain in the market beyond 2020, that there will be no or minimal enforcement, and the political uncertainty surrounding upcoming efficiency regulations, EVT will model the shift to a baseline of 45 lumens per watt starting in 2021.

The appropriate adjustments as a percentage of the base year savings for each fixture type are provided below.[1]

		Bulb Wattages Assumed in Calculation				**2021 Savings Adjustment**	
Fixture Type	**LED Wattage**	**2016 - 2020**		**2021**		**Efficient Products,**	**Residential and Multifamily**
		Efficient	**Residential and**	**Efficient**	**Residential and**		

Type		Products, SMARTLIGHT	Multifamily New Construction	Products, SMARTLIGHT	Multifamily New Construction	SMARTLIGHT	New Construction
Indoor Fixtures	21.3	82.2	48.2	49.0	36.8	45.5%	57.6%
Task/ Under Cabinet Fixtures	12.8	46.9	27.2	22.9	20.6	29.7%	54.3%
Outdoor Fixtures	16.5	74.0	45.6	40.1	36.1	40.9%	67.3%
Downlight Fixtures	18.2	64.2	40.4	36.0	32.4	38.7%	63.9%

Load Shapes

Market	Location	Fixture Type	Loadshape
Residential (Efficient Products, SMARTLIGHT, and New Construction)	NA	Indoor Fixtures	Residential Indoor Lighting
		Task/ Under Cabinet Fixtures	
		Downlight Fixtures	
		Outdoor Fixtures	Residential Outdoor Lighting
Commercial (Efficient Products and SMARTLIGHT)	NA	Indoor Fixtures	Commercial EP Lighting with cooling bonus
		Task/ Under Cabinet Fixtures	
		Downlight Fixtures	
		Outdoor Fixtures	Commercial Outdoor Lighting
Multifamily New Construction	In Unit	Indoor Fixtures	Residential Indoor Lighting
		Downlight Fixtures	
	Indoor Hallway/Stair	Indoor Fixtures	Flat (8760 hours)
		Downlight Fixtures	
	Laundry	Indoor Fixtures	Commercial Indoor Lighting - Blended
		Downlight Fixtures	
	NA	Outdoor Fixtures	Residential Outdoor Lighting
	NA	Task/ Under Cabinet Fixtures	Residential Indoor Lighting

1a Residential Indoor Lighting
2a Residential Outdoor Lighting
12d Commercial Indoor Lighting - Blended
13a Commercial Outdoor Lighting
25a Flat (8760 hours)
101c Commercial EP Lighting with cooling bonus

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
1	Residential Indoor Lighting	Active	36.9 %	35.0 %	13.0 %	15.1 %	29.8 %	8.2 %
2	Residential Outdoor Lighting	Active	20.5 %	50.6 %	6.1 %	22.8 %	34.6 %	1.8 %
12	Commercial Indoor Lighting - Blended	Active	48.8 %	19.5 %	22.2 %	9.5 %	46.9 %	67.9 %
13	Commercial Outdoor Lighting	Active	20.5 %	50.6 %	6.1 %	22.8 %	70.2 %	3.7 %
25	Flat (8760 hours)	Active	31.7 %	34.9 %	15.9 %	17.5 %	100.0 %	100.0 %
101	Commercial EP Lighting with cooling bonus	Active	47.7 %	19.2 %	23.0 %	10.1 %	33.8 %	68.1 %

Net Savings Factors

Measures

LFHRDLED	LED Recessed Surface or Pendant Downlight Rx
LFHLEDOU	LED Outdoor Fixture
LFHLEDIN	LED Indoor Fixture
LFHLEDTU	LED Task/Undercabinet Fixture

Tracks [Base Track]

6013UPST [is base track]	Upstream - Commercial

6018LINC [is base track]	LIMF NC
6019MFNC [is base track]	MF Mkt NC
6032EPEP [is base track]	Efficient Products - Residential
6032UPST [6032EPEP]	Upstream - Residential

Lifetimes

Lifetime is a function of the rated life[13] and average hours of use of the luminaire[14]

Fixture Type	**Rated Life (Hours)**		**Lifetime (Years)**	
	Residential	**Commercial**	**Residential**	**Commercial**
Indoor Fixtures	43,000	47,000	15.0 4.9 9.8	12.8
Task/ Under Cabinet Fixtures	37,000	40,000	15.0	15.0
Outdoor Fixtures	49,000	49,000	15.0	12.4
Downlight Fixtures	38,000	43,000	15.0 4.3 8.7	12.2

Persistence

The persistence factor is assumed to be one.

Measure Cost

The incremental cost for this measure is provided in the table below[15]

Fixture Type	**Incremental Cost**
Indoor Fixture	$32
Task/Under Cabinet Fixture	$25
Outdoor Fixture	$32
Downlight Fixtures	$25

O&M Cost Adjustments

To account for the shift in baseline due to EISA requirements, the levelized baseline replacement cost over the lifetime of the LED is calculated. The key assumptions used in this calculation are documented below.

	EISA 2016-2020 Compliant	**EISA 2021 Compliant**
Replacement Cost	$1.50	$2.50
Component Life (hours)	1,000	10,000
Years	2016 – 2020	2021 on

The calculation results in the following assumptions of equivalent annual baseline replacement cost:[1]

Market	**Fixture Type**	**Annual Baseline O&M Assumption**		
		2018	**2019**	**2020**
Residential and Multifamily	**Indoor Fixture and Downlight (In Unit)**	$0.43	$0.33	$0.23
	Task / Under Cabinet	$0.29	$0.21	$0.14
	Outdoor	$1.02	$0.82	$0.61
	Indoor Fixture (Hall / Stair)	$9.00	$6.71	$4.35
	Indoor Fixture	$2.85	$2.23	$1.60

Multifamily	**(Laundry)**			
	Downlight (Hall / Stair)	$9.81	$7.24	$4.59
	Downlight (Laundry)	$3.05	$2.36	$1.66
Commercial	**Indoor Fixture**	$2.07	$1.67	$1.25
	Task / Under Cabinet	$1.31	$1.06	$0.80
	Outdoor	$2.29	$1.83	$1.36
	Downlight	$2.03	$1.62	$1.19

Footnotes

[1] See file EVT_Solid State (LED) Fixtures_Analysis_Oct 2018.xlsx for calculation details.

[2] Lifetime ISR based on methodology from Chapter 21: Residential Lighting Evaluation Protocol of the Uniform Methods Project. Using a 1st Year ISR of 92.5% (average of 1st year ISR of 90% from NMR Group, Inc., "Efficiency Maine Retail Lighting Program Overall Evaluation Report FINAL," 4/16/2015. Page 14, Table 2-1 and 95% from NMR Group, Inc., "Connecticut LED Lighting Study Report (R154) FINAL," 1/28/2016. Page V, Table 1) and a discount rate of 3.00% based on the Vermont societal cost test, the lifetime ISR after three years is 97%. See file EVT_Solid State (LED) Fixtures_Analysis_Oct 2018.xlsx for calculaton details.

[3] A leakage rate of 1.5% was agreed to by EVT and DPS during October 2017 TAG. This value is an estimate based on leakage rates used by other programs, geographic factors, and a consideration of similar lighting programs in surrounding service territories.

[4] The default waste heat factor for demand and energy is from KEMA, "NEEP C&I Lighting Loadshape Project, KEMA," 2011. The report modeled the energy savings per building type and the associated energy, demand, and coincident demand interactive effects. A description of how the interactive effects were developed is on page 28 of the report, including details about how temperature balance points, equipment efficiencies, and heat to space factors influenced each building's designated interactive effects. The building types were weighted for the NE-North Weather climate zone in order to come up with a single prescriptive default value for both demand and energy lighting waste heat factors. For more information, please see the spreadsheet, "EVT Lighting WHF Research_Prescriptive.xlsx".

[5] Commercial hours based on 3-year weighted average for fixtures rebated through Efficiency Vermont's Business Energy Services prescriptive program, through 12/14/2015. See Rx_C&I_LED_hours.xlsx for analysis

[6] Based on a household average 2.7 hours of use per day. NMR, "Northeast Residential Lighting Hours-of-Use Study", 5/5/2014. Page 34, Table 3-1.

[7] Estimated at 2 hours per day.

[8] Based on a household exterior average 5.6 hours of use per day. NMR, "Northeast Residential Lighting Hours-of-Use Study", 5/5/2014. Page 34, Table 3-1.

[9] Based on average efficiency for furnaces and boilers of varied sizes in ASHRAE 90.1.1999, assumed to represent typical commercial building stock in Vermont.

[10] The typical aspect ratio is sourced from PNNL, "Analysis of Daylighting Requirements within ASHRAE Standard 90.1, PNNL," 2013, from the Executive Summary on page v. The aspect ratio is sourced from 1 of 16 PNNL prototype building models. The 60% default value is from the medium office building model.

[11] From "Calculating lighting and HVAC Interactions", Table 1, ASHRAE Journal November 1993.

[12] 2009 ASHRAE Handbook Fundamentals (p. 16.2): "Conventional all-air air-handling systems for commercial and institutional buildings have approximately 10 to 40% outside air."

[13] Average rated lives are based on the average rated lives of fixtures available on the ENERGY STAR qualifying list as of 10/27/2015.

[14] Lifetimes are capped at 15 years even when the rated life/hours of use are higher.

[15] Incremental costs for downlight fixtures are based on an average cost of $45 for commercial downlight fixtures rebated through Efficiency Vermont's prescriptive program in 2015 and a baseline cost of $20 (typical cost of downlight housing ($10) + trim kit ($7) + BR30 lamp ($3) using Home Depot as a reference). Incremental costs for indoor fixtures, task/under cabinet fixtures, and outdoor fixtures are based on the EPA/ENERGY STAR Light Fixture and Ceiling Fan Calculator.xlxs;

LED Linear Replacement Lamps

Measure Number:	IV-E-16 c
Portfolio:	EVT TRM Portfolio 2018-10
Status:	Inactive
Effective Date:	2018/1/1
End Date:	2018/12/31
Program:	Efficient Products Program
End Use:	Lighting

Update Summary

The following revisions have been made to the measure:

- Updated to use Loadshape #101 for commercial lighting
- Removed reference to separate cooling loadshape
- Added a footnote to show the basis of the new loadshape
- Added 6013EPEP track

Referenced Documents

- Calculating Lighting and HVAC Interactions_ASHRAE
- NMR Group, Inc., "Northeast Residential Lighting Hours-of-Use Study," prepared for CT Energy Efficiency Board, Cape Light Compact, Massachusetts Energy Efficiency Advisory Council, National Grid MA, National Grid RI, NYSERDA, Northeast Utilities, May 5, 2
- NMR_Efficiency-Maine-Retail-Lighting-Program-Evaluation-Report-2015
- NMR_R154 - CT LED Lighting Study_Final Report_1
- PNNL_Analysis of Daylighting Requirements_Aug 2013
- NEEP_CI Lighting Loadshape_Jul 2011
- EVT Lighting WHF Research_Prescriptive
- EVT_LED Linear Replacement Lamps_Analysis_Dec 2017

Description

Efficiency Vermont will offer instant rebates for LED linear replacement lamps to residential or commercial customers at particpatng retail locations.

Baseline Efficiencies

Refer to the table "LED Linear Replacement Lamps (TLED) Wattage Assumptions and Deemed Savings" in the Reference Tables section for baseline lamp descriptions and wattages.

Efficient Equipment

Refer to the table "LED Linear Replacement Lamps (TLED) Wattage Assumptions and Deemed Savings" in the Reference Tables section for efficient lamp descriptions and wattages.

Algorithms

Electric Demand Savings

$\Delta kW = ((Watts_{BASE} - Watts_{EE}) /1000) \times ISR \times WHF_d \text{ x } (1 - LR)$

Symbol Table

Electric Energy Savings

$\Delta kWh = ((Watts_{BASE} - Watts_{EE}) / 1000) \times HOURS \times ISR \times WHF_e \text{ x } (1 - LR)$

Symbol Table

Fossil Fuel Savings

$\Delta MMBTU_{WH} = (\Delta kWh / WHF_e) \times 0.003412 \times (1 - OA) \times AR \times HF \times DFH / \eta Heat$

Where:

ΔkW = Gross customer connected load kW savings for the measure

ΔkWh = Gross customer annual kWh savings for the measure

$\Delta MMBTU_{WH}$ = Gross customer annual heating MMBTU fuel increased usage for the measure from the reduction in lighting heat

$\eta Heat$ = Average heating system efficiency

= 79%[6]

0.003412 = Conversion from kWh to MMBtu

AR = Typical aspect ratio factor. The ASHRAE heating factor applies to perimeter zone heat, therefore it must be adjusted to account for lighting in core zones. It is assumed that 60%[7] is the typical square footage of commercial buildings within 15 feet of exterior wall.

DFH = Percent of lighting in heated spaces. For prescriptive lighting, assumed to be 95%

HF = ASHRAE heating factor of 0.39 for lighting waste heat for Burlington, Vermont for commercial lighting,[8] assumed to be 0.0 for residential lighting

HOURS = Average hours of use per year

Market	Annual Hours
Commercial[4]	3,555
Residential[5]	986

ISR = In service rate or the percentage of units rebated that actually get used

= 97%[1]

LR = Leakage Rate to account for bulbs sold to customers outside of the program area

= 0.015[2]

OA = Outside Air - the average percent of the supply air that is Outside Air, assumed to be 25%[9]

$Watts_{BASE}$ = Baseline connected kW. See "LED Linear Replacement Lamps (TLED) Wattage Assumptions and Deemed Savings" table within the Reference Tables section of this measure.

$Watts_{EE}$ = Energy efficient connected kW. See "LED Linear Replacement Lamps (TLED) Wattage Assumptions and Deemed Savings" tablevwithin the Reference Tables section of this measure.

WHF_d = Waste heat factor for demand to account for cooling savings from efficient lighting. For prescriptive commercial lighting in existing buildings, the default value is 1.102.[3] The cooling savings are only added to the summer peak savings. The value for residential lighting is assumed to be 1.0.

WHF_e = Waste heat factor for energy to account for cooling savings from efficient lighting. For prescriptive commercial lighting in existing buildings, the default value is 1.036.[3] The value for residential lighting is assumed to be 1.0.

Load Shapes

Residential: Loadshape #1: Residential Indoor Lighting

Commercial: Loadshape #101: Commercial EP Lighting with Cooling Bonus [10]

1a Residential Indoor Lighting
101c Commercial EP Lighting with cooling bonus

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
1	Residential Indoor Lighting	Active	36.9 %	35.0 %	13.0 %	15.1 %	29.8 %	8.2 %
101	Commercial EP Lighting with cooling bonus	Active	47.7 %	19.2 %	23.0 %	10.1 %	33.8 %	68.1 %

Net Savings Factors

Measures

LBLT8LED	LED Linear Replacement

Tracks [Base Track]

6032EPEP [is base track]	Efficient Products - Residential
6013EPEP [6032EPEP]	Efficient Products - Commercial

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Efficient Products - Residential	6032EPEP	LBLT8LED	1.00	1.00

Persistence

The persistence factor is assumed to be one.

Lifetimes

Lifetime is the average rated life (hours) of the product, divided by annual operating hours. All lifetimes are capped at 15 years.

The measure lifetime for LED linear replacement lamps is 14.1 years for commercial applications and 15 years for residential applications.[11]

Measure Cost

The efficient, baseline, and incremental costs are provided below.[12]

EE Measure Description	EE Lamp Cost	Baseline Description	Base Lamp Cost	Incremental Cost
LED Linear Replacement Lamp (TLED), < 1200 lumens	$17.75	F17T8 Standard Lamp - 2-4 foot	$4.49	$13.26
LED Linear Replacement Lamp (TLED), 1200-2400 lumens	$18.00	F32T8 Standard Lamp - 4 foot	$3.00	$15.00
LED Linear Replacement Lamp (TLED), > 2400 lumens	$24.25	F32T8/HO Standard Lamp - 4 foot	$11.00	$13.25

O&M Cost Adjustments

EE Measure Description	EE Lamp Cost[12]	EE Lamp Life (hrs)[11]	Baseline Description	Base Lamp Cost[12]	Base Lamp Life (hrs)[13]	Base Lamp Rep. Labor Cost[14]
LED Linear Replacement Lamp (TLED), < 1200 lumens	$17.75	50,000	F17T8 Standard Lamp - 2-4 foot	$4.49	30,000	$2.67
LED Linear Replacement Lamp (TLED), 1200-2400 lumens	$18.00	50,000	F32T8 Standard Lamp - 4 foot	$3.00	24,000	$2.67
LED Linear Replacement Lamp (TLED), > 2400 lumens	$24.25	50,000	F32T8/HO Standard Lamp - 4 foot	$11.00	18,000	$2.67

Reference Tables

LED Linear Replacement Lamps (TLED) Wattage Assumptions and Deemed Savings

EE Measure Description	WattsEE	Baseline Description	$Watts_{Base}$	Market	ΔkW	ΔkWh	ΔMMBtu
LED Linear Replacement Lamp (TLED), < 1200 lumens	8.9	F17T8 Standard Lamp - 2-4 foot	15	Commercial	0.00642	21.5	0.015
				Residential	0.00582	5.7	N/A
LED Linear Replacement Lamp (TLED), 1200-2400 lumens	15.8	F32T8 Standard Lamp - 4 foot	28	Commercial	0.01303	43.6	0.030
				Residential	0.01183	11.7	N/A
LED Linear Replacement Lamp (TLED), > 2400 lumens	22.9	F32T8/HO Standard Lamp - 4 foot	42	Commercial	0.01985	66.4	0.046
				Residential	0.01802	17.8	N/A

See file EVT_LED Linear Replacement Lamps_Analysis_Dec 2017.xlsx for deeemd savings calculations.

Footnotes

[1] Lifetime ISR based on methodology from Chapter 21: Residential Lighting Evaluation Protocol of the Uniform Methods Project. Using a 1st Year ISR of 92.5% (average of 1st year ISR of 90% from NMR Group, Inc., "Efficiency Maine Retail Lighting Program Overall Evaluation Report FINAL," 4/16/2015. Page 14, Table 2-1 and 95% from NMR Group, Inc., "Connecticut LED Lighting Study Report (R154) FINAL," 1/28/2016. Page V, Table 1) and a discount rate of 3.00% based on the Vermont societal cost test, the lifetime ISR after three years is 97%.

[2] A leakage rate of 1.5% was agreed to by EVT and DPS during October 2017 TAG. This value is an estimate based on leakage rates used by other programs, geographic factors, and a consideration of similar lighting programs in surrounding service territories.

[3] The default waste heat factor for demand and energy is from KEMA, "NEEP C&I Lighting Loadshape Project, KEMA," 2011. The report modeled the energy savings per building type and the associated energy, demand, and coincident demand interactive effects. A description of how the interactive effects were developed is on page 28 of the report, including details about how temperature balance points, equipment efficiencies, and heat to space factors influenced each building's designated interactive effects. The building types were weighted for the NE-North Weather climate zone in order to come up with a single prescriptive default value for both demand and energy lighting waste heat factors. For more information, please see the spreadsheet, "EVT Lighting WHF Research_Prescriptive.xlsx".

[4] Operating hours for commercial lamps are based on Efficiency Vermont data for prescriptive applications from 7/1/2015 through 10/24/2016. See file EVT_LED Linear Replacement Lamps_Analysis_Dec 2017.xlsx for analysis.

[5] Operating hours for residential lamps are based on a household average 2.7 hours of use per day. NMR, "Northeast Residential Lighting Hours-of-Use Study", 5/5/2014. Page 34, Table 3-1.

[6] Based on average efficiency for furnaces and boilers of varied sizes in ASHRAE 90.1.1999, assumed to represent typical commercial building stock in Vermont.

[7] The typical aspect ratio is sourced from PNNL, "Analysis of Daylighting Requirements within ASHRAE Standard 90.1, PNNL," 2013, from the Executive Summary on page v. The aspect ratio is sourced from 1 of 16 PNNL prototype building models. The 60% default value is from the medium office building model.

[8] From "Calculating lighting and HVAC interactions", Table 1, ASHRAE Journal November 1993.

[9] 2009 ASHRAE Handbook Fundamentals (p. 16.2): "Conventional all-air air-handling systems for commercial and institutional buildings have approximately 10 to 40% outside air."

[10] Based on Commercial "Small" Lighting coincidence factors from KEMA; "C&I Lighting Load Shape Project Final Report," July 19, 2011, prepared for the Regional Evaluation, Measurement and Verification Form, submitted to NEEP. The winter coincidence factor has been adjusted to remove the cooling bonus from winter peak demand.

[11] Based on the DLC 4.0 specification, the rated lifetime for LED linear replacement lamps is 50,000 hours.

[12] Efficient lamp costs are based on Efficiency Vermont data for prescriptive applications from 7/1/2015 through 10/24/2016. Baseline lamp costs are based on a review of Philips brand products on bulbs.com. See file EVT_LED Linear Replacement Lamps_Analysis_Dec 2017.xlsx for more details.

[13] Baseline lamp hours for LED linear replacement lamps are the rated annual lifetime for Philips brand bulbs on bulbs.com. See reference file EVT_LED Linear Replacement Lamps_Analysis_Dec 2017.xlsx for more details.

[14] Lamp replacement labor costs are based on 8 minutes of labor at $20/hour.

Efficient Pool Pumps

Measure Number:	IV-H-2 b
Portfolio:	82
Status:	Inactive
Effective Date:	2013/1/1
End Date:	2018/12/31
Program:	Efficient Products Program
End Use:	Motors

Referenced Documents

- CEE Efficient Residential Swimming Pool Initiative; http://www.ceeforum.org/system/files/private/4114/cee_res_swimmingpoolinitiative_07dec2012_pdf_12958.pdf
- CEE Draft Pool Pump Energy Savings Calculator; http://www.ceeforum.org/content/cee-draft-pool-pump-energy-savings-calculator

Description

A residential pool with a single speed pool pump motor can be replaced or retrofitted with a more efficient ENERGY STAR two-speed or variable speed model of equivalent or lesser horsepower. Measure assumes that both the baseline and the efficient motor have a timer.

Estimated Measure Impacts

	Average Annual MWH Savings per unit	Average number of measures per year	Average Annual MWH savings per year
Two Speed pump	1.6	10	165
Variable Speed pump	2.1	20	42

Note: These estimates assume an average motor size of 1 HP.

Algorithms

Electric Energy Savings

$\Delta kWh_{TwoSpeed}$ = ((12 * 62 * 60)/ 2.0) – (((2 * 62 * 60)/2.0 + ((8 * 33.2 * 60)/5.0))) / 1000 * 107

= 1649 kWh

$\Delta kWh_{VariableSpeed}$ = ((12 * 62 * 60)/ 2.0) – (((1 * 50 * 60)/3.0) + ((1 * 33 * 60)/5.0)) + ((12 * 20 * 60)/12.0))) / 1,000 * 107

= 2111 kWh

$\Delta kWh_{TwoSpeed}$ $= ((Hrs/Day_{Base} \times GPM_{Base} \times 60)/EF_{Base})) - (((Hrs/Day_{TwoSpeedHigh} \times GPM_{TwoSpeedHigh} \times 60)/EF_{TwoSpeedHigh})) + ((Hrs/Day_{TwoSpeedLow} \times GPM_{TwoSpeedLow} \times 60)/EF_{TwoSpeedLow}))) / 1000 \times Days$

$\Delta kWh_{VariableSpeed}$ $= ((Hrs/Day_{Base} \times GPM_{Base} \times 60)/EF_{Base})) - (((Hrs/Day_{VarSpeedHigh} \times GPM_{VarSpeedHigh} \times 60)/EF_{VarSpeedHigh})) + ((Hrs/Day_{VarSpeedLow} \times GPM_{VarSpeedLow} \times 60)/EF_{VarSpeedLow})) + ((Hrs/Day_{VarSpeedLower} \times GPM_{VarSpeedLower} \times 60)/EF_{VarSpeedLower}))) / 1000 \times Days$

Symbol Table

Demand Savings

The methodology and all assumptions are taken from the CEE Pool Pump Energy Savings Calculator unless otherwise noted; http://www.ceeforum.org/content/cee-draft-pool-pump-energy-savings-calculator. See "cee_resapp_poolpumpsavingscalc_07dec2012_EVT.xlsx" for complete calculation.

$\Delta kW_{TwoSpeed}$ = 22.3/12 – 6.9/10

= 1.17kW

$\Delta kW_{VariableSpeed}$ = 22.3/12 – 2.6/12

= 1.64 kW

$\Delta kW_{TwoSpeed}$ $= kWh/day_{Base} / Hrs/day_{Base} - kWh/day_{TwoSpeed} / Hrs/day_{TwoSpeed}$

$\Delta kW_{VariableSpeed}$ $= kWh/day_{Base} / Hrs/day_{Base} - kWh/day_{VariableSpeed} / Hrs/day_{VariableSpeed}$

Where:

$\Delta kW_{TwoSpeed}$ = gross customer annual kW savings for the two speed measure

$\Delta kW_{VariableSpeed}$ = gross customer annual kW savings for the variable speed measure

$\Delta kWh_{TwoSpeed}$ = gross customer annual kWh savings for the two speed measure

$\Delta kWh_{VariableSpeed}$ = gross customer annual kWh savings for the variable speed measure

Days = Number of days swimming pool is operational
=107[1]

EF_{Base} = Energy Factor of baseline single speed pump (gal/Wh)
= 2.0

$EF_{TwoSpeedHigh}$ = Energy Factor of two speed pump at High Speed (gal/Wh)
= 2.0

$EF_{TwoSpeedLow}$ = Energy Factor of two speed pump at Low Speed (gal/Wh)
= 5.0

$EF_{VarSpeedHigh}$ = Energy Factor of variable speed pump at High Speed (gal/Wh)
= 3.0

$EF_{VarSpeedLow}$ = Energy Factor of two speed pump at Low Speed (gal/Wh)
= 5.0

$EF_{VarSpeedLower}$ = Energy Factor of two speed pump at Lower Speed (gal/Wh)
= 12.0

GPM_{Base} = Gallons per minute flow of single speed pump
= 62[2]

$GPM_{TwoSpeedHigh}$ = Gallons per minute flow of two speed pump at high speed
= 62[3]

$GPM_{TwoSpeedLow}$ = Gallons per minute flow of two speed pump at low speed
= 33.2[4]

$GPM_{VarSpeedHigh}$ = Gallons per minute flow of variable speed pump at high speed
= 50[5]

$GPM_{VarSpeedLow}$ = = Gallons per minute flow of variable speed pump at low speed
= 33[6]

$GPM_{VarSpeedLower}$ = Gallons per minute flow of variable speed pump at lower speed
= 20[7]

$Hrs/day_{TwoSpeed}$ = 10 hours

$Hrs/day_{VariableSpeed}$ = 14 hours

Hrs/day_{Base} = 12 hours

Hrs/Day_{Base} = Run hours of single speed pump
= 12

$Hrs/Day_{TwoSpeedHigh}$ = Run hours of variable speed pump at high speed
= 1

$Hrs/Day_{TwoSpeedLow}$ = Run hours of two speed pump at low speed
= 8

$Hrs/Day_{VarSpeedHigh}$ = Run hours of variable speed pump at high speed
= 1

$Hrs/Day_{VarSpeedLow}$ = Run hours of variable speed pump at high speed
= 1

$Hrs/Day_{VarSpeedLower}$ = Run hours of variable speed pump at lower speed
= 12

kWh/day_{Base} = Daily energy consumption of baseline pump(calculated using algorithm and variables above)
= 22.3 kWh

$kWh/day_{TwoSpeed}$ = Daily energy consumption of two speed pump(calculated using algorithm and variables above)
= 6.9 kWh

$kWh/day_{VariableSpeed}$ = Daily energy consumption of variable speed pump(calculated using algorithm and variables above)
= 2.6 kWh

Baseline Efficiencies

Baseline efficiency is a single speed pool pump with a timer.

High Efficiency

The high efficiency level is an ENERGY STAR[8] two-speed or variable speed pool pump with a timer.

Operating Hours

Variable hours of use - See Algorithm sections above.

Load Shapes

Residential Efficient Pool Pump

100a Efficient Pool Pump

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
100	Efficient Pool Pump	Active	0.0 %	0.0 %	65.0 %	35.0 %	0.0 %	83.1 %

Net Savings Factors

Measures

MTRPLPMP	Motor, Pool Pump

Tracks [Base Track]

6032EPEP [is base track]	Efficient Products - Residential

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Efficient Products - Residential	6032EPEP	MTRPLPMP	1.00	1.00

Persistence

The persistence factor is assumed to be one.

Lifetimes

The life of the equipment is 10 years.[9]

Measure Cost

The incremental cost for this measure is $100 for two speed pool pumps and $846 for variable speed pool pumps.[10]

O&M Cost Adjustments

There are no operation and maintenance cost adjustments for this measure.

Fossil Fuel Description

There are no fossil fuel algorithms or default values for this measure.

Footnotes

[1] Assumes pool operational between June 1st and September 15th

[2] Average GPM from single speed 1HP motors in CEC database.

[3] Average GPM from 1HP two speed motors at high speed in CEC database.

[4] Average GPM from 1HP two speed motors at low speed in CEC database.

[5] Average GPM from 1HP variable speed motors at high speed in CEC database.

[6] Average GPM from 1HP variable speed motors at low speed in CEC database.

[7] Average GPM from 1HP variable speed motors at lower speed in CEC database.

[8] See http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=PP.

[9] The CEE Efficient Residential Swimming Pool Initiative, p18, indicates that the average motor life for pools in use year round is 5-7 years. For pools in use for under a third of a year, you would expect the lifetime to be higher so 10 years is selected as an assumption.

[10] CEE Efficient Residential Swimming Pool Initiative, p34;

http://www.ceeforum.org/system/files/private/4114/cee_res_swimmingpoolinitiative_07dec2012_pdf_12958.pdf

ENERGY STAR Retail Products Platform

Measure Number: IV-J-1 c
Portfolio: EVT TRM Portfolio 2017-12
Status: Active
Effective Date: 2018/1/1
End Date: [None]
Program: Efficient Products Program
End Use: Multiple

Update Summary

Modification to existing ENERGY STAR Retail Products Platform measure to:

- Add two dehumidifier tiers: ENERGY STAR and ENERGY STAR Most Efficient. The dehumidifier characterization was copied directly from the ENERGY STAR Dehumidifers measure, effective on 1/1/2018 and approved by DPS under EVT TRM Portfolio 2017-12.
- Update clothes washer assumptions to match updated Efficient Clothes Washers measure, effective 1/1/2018 and approved by DPS under EVT TRM Portfolio 2017-09.

Referenced Documents

- Refrigerator Standards and Savings 2014
- Refrigerator kW Calculations 2016
- 2016 Clothes Dryer Analysis
- epa-rpp-product-analysis-evt-2017
- 2018-clothes-washer-savings-xlsx
- DOE Energy Conservation Standards for Dehumidifiers, July 2012
- ENERGY STAR Dehumidifier V6 EVT TRM Analysis

Description

This measure describes the ENERGY STAR Retail Products Platform (ESRPP), an initiative facilitated by the U.S. Environmental Protection Agency. This program will engage retailers through midstream/upstream incentive payments to increase the demand for and supply of the most energy efficient residential plug-load and appliance products on the market, driving greater sales of select ENERGY STAR certified products to customers. With a combination of incentives and engagement, retailers will assort, stock, and promote more energy efficient models than they would have absent the program. Covered products include sound bars, freezers, refrigerators, dehumidifiers, clothes dryers, clothes washers, room air cleaners, and room air conditioners. This measure applies to Time of Sale program delivery. All reference file documentation provided by EPA is cited and listed on the appropriate tabs of the EPA RPP Analysis_EVT_2017.xlsx spreadsheet.

Baseline Efficiencies

The baseline and efficient cases for each product are listed in the table below.

Product	Baseline Efficiency	High Efficiency
ENERGY STAR Sound Bars	Weighted average of electric energy consumption[1] for both non-ENERGY STAR and ENERGY STAR models	50% more efficient[2] than ENERGY STAR Version 3.0 specification, effective May 1, 2013
ENERGY STAR Freezers	Federal standard, effective September 15, 2014	ENERGY STAR Version 5.0 specification, effective September 15, 2014 and 5% more efficient than ENERGY STAR
ENERGY STAR and CEE-Qualified Refrigerators	Federal standard, effective September 15, 2014	ENERGY STAR Version 5.0 specification, effective September 15, 2014/CEE Tier 1, CEE Tier 2, and CEE Tier 3
ENERGY STAR Dryer (Electric or Gas) and 2014 Emerging Technology Award Dryer (Electric Vented Hybrid Heat Pump, Electric Ventless Hybrid Heat Pump, or Electric Ventless Full Heat Pump)	The baseline combined energy factor (CEF) was derived in the ENERGY STAR Version 1.0 analysis by multiplying 2015 federal standards by the average change in a dryers' assessed CEF between the required (Appendix D1) and optional (Appendix D2) test procedure required by the ENERGY STAR eligibility requirements.	ENERGY STAR Version 1.0 specification, effective January 1, 2015 and 2014 Emerging Technology Award criteria[3]
ENERGY STAR and CEE-Qualified Clothes Washers	Federal standard, effective January 1, 2018	ENERGY STAR Version 8.0 specification, effective February 5, 2018, CEE Tier 2, and CEE Advanced Tier
ENERGY STAR Room Air	Room air cleaners that do not meet	30 % more efficient and 50% more

Cleaners	ENERGY STAR efficiency requirements	efficient than ENERGY STAR Version 1.2 specification, effective July 1, 2004
ENERGY STAR Room Air Conditioners	Federal standard, effective June 1, 2014	ENERGY STAR Version 4.0 specification, effective October 26, 2015
ENERGY STAR and ENERGY STAR Most Efficient Dehumidifiers	Federal standard, effective October 1, 2012	ENERGY STAR Version 4.0 specification, effective October 25, 2016, and ENERGY STAR Most Efficient 2018 Criteria, effective January 1, 2018

Efficient Equipment

See 'Baseline & Efficient" table within "Baseline Efficiencies" section.

Algorithms

Electric Demand Savings

$\Delta kW = \Delta kWh/HOURS$

Symbol Table

Electric Energy Savings

The baseline and energy efficient kWh consumption and the kWh and kW savings for each product are provided in the table below.[9]

Product	kWh_{BASE}	kWh_{EE}	ΔkWh	ΔkW
ENERGY STAR +50% Sound Bars	48.7	24.7	24.0	0.00274
ENERGY STAR Freezers (Upright)	438.6	394.8	43.8	0.00516
ENERGY STAR Freezers (Chest)	239.3	215.3	24.0	0.00283
ENERGY STAR Freezers (Unknown Type)[10]	312.5	281.3	31.2	0.00368
ENERGY STAR +5% Freezers (Upright)	438.6	375.1	63.5	0.00749
ENERGY STAR +5% Freezers (Chest)	239.3	204.6	34.7	0.00409
ENERGY STAR Freezers +5% (Unknown Type)[10]	312.5	267.2	45.3	0.00534
ENERGY STAR/CEE Tier 1 Refrigerators	592	533	59	0.0070
CEE Tier 2 Refrigerators	592	503	89	0.0105
CEE Tier 3 Refrigerators	592	474	118	0.0140
ENERGY STAR Dryer (Electric)	See spreadsheet Clothes Dryer Analysis 2016.xlxs		194	0.60
ENERGY STAR Dryer (Gas)	See spreadsheet Clothes Dryer Analysis 2016.xlxs		36	0.11
2014 Emerging Technology Award Dryer (Electric Vented Hybrid Heat Pump)	See spreadsheet Clothes Dryer Analysis 2016.xlxs		366	1.14
2014 Emerging Technology Award Dryer (Electric Ventless Hybrid Heat Pump)	See spreadsheet Clothes Dryer Analysis 2016.xlxs		457	1.42
2014 Emerging Technology Award Dryer (Electric Ventless Full Heat Pump)	See spreadsheet Clothes Dryer Analysis 2016.xlxs		658	2.04
ENERGY STAR Clothes Washers	See spreadsheet 2018 Clothes Washer Analysis.xlsx		88.1	0.274
CEE Tier 2 Clothes Washers	See spreadsheet 2018 Clothes Washer Analysis.xlsx		120.3	0.374
CEE Advanced Tier Clothes Washers	See spreadsheet 2018 Clothes Washer Analysis.xlsx		128.2	0.398
ENERGY STAR Room Air Cleaner	531.0	317.1	213.9	0.03663
ENERGY STAR +30% Room Air Cleaners	531.0	222.0	309.0	0.05291
ENERGY STAR +50% Room Air Cleaners	531.0	158.5	372.4	0.06377
ENERGY STAR Room Air Conditioners	114.7	104.0	10.7	0.07589
ENERGY STAR Dehumidifiers	See spreadsheet ENERGY STAR Dehumidifier V6 EVT TRM Analysis.xlsx		229	0.140
ENERGY STAR Most Efficient Dehumidifiers: Stand Alone	See spreadsheet ENERGY STAR Dehumidifier V6 EVT TRM Analysis.xlsx		313	0.192

$\Delta kWh = kWh_{Base} - kWh_{EE}$

Symbol Table

Fossil Fuel Savings

The prescriptive annual MMBtu savings per unit for clothes dryers are:[11]

	Total MMBtu	NG	LP	Oil	Wood
ENERGY STAR (Electric)	-0.02	-0.01	0.00	-0.01	0.00
ENERGY STAR (Gas)	0.50	0.16	0.35	-0.01	0.00
2014 Emerging Technology Award Vented Hybrid Heat Pump (Electric)	-0.05	-0.01	-0.01	-0.02	-0.01
2014 Emerging Technology Award Ventless Hybrid Heat Pump (Electric)	1.11	0.19	0.15	0.53	0.24
2014 Emerging Technology Award Ventless Full Heat Pump (Electric)	0.77	0.12	0.10	0.36	0.19

The prescriptive annual MMBtu savings per unit for clothes washers are:[12]

	NG	LP	Oil

ENERGY STAR Most Efficient Dehumidifiers: Whole House	See spreadsheet ENERGY STAR Dehumidifier V6 EVT TRM Analysis.xlsx	350	0.214

ENERGY STAR Clothes Washers	0.03	0.04	0.00
ENERGY STAR CEE Tier 2 Clothes Washers	0.17	0.19	0.10
CEE Advanced Tier Clothes Washers	0.17	0.20	0.10

Where:

ΔkW = Gross customer connected load kW savings for the measure

ΔkWh = Gross customer annual kWh savings for the measure

HOURS = Average hours of use per year; see table below

Product	HOURS
Sound Bars	8,760
Freezers	8,477[4]
Refrigerators	8,477[4]
Clothes Dryers	322[5]
Clothes Washers	322[5]
Room Air Cleaners	5,840[6]
Room Air Conditioners	141[7]
Dehumidifiers	1,632[8]

kWh_{Base} = Baseline kWh consumption per year

kWh_{EE} = Energy efficient kWh consumption per year

Load Shapes

4b Residential Refrigerator
9a Residential Clothes Washer
73a Residential - Dehumidifier
94a Efficient Television
118a Room Air Cleaner
99b Room Air Conditioning

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
4	Residential Refrigerator	Active	30.8 %	33.0 %	17.1 %	19.1 %	79.6 %	100.0 %
9	Residential Clothes Washer	Active	42.0 %	28.8 %	16.9 %	12.3 %	4.4 %	3.3 %
73	Residential - Dehumidifier	Active	15.9 %	17.5 %	31.7 %	34.9 %	0.0 %	35.3 %
94	Efficient Television	Active	48.0 %	19.0 %	24.0 %	9.0 %	22.0 %	17.0 %
118	Room Air Cleaner	Active	31.7 %	34.9 %	15.9 %	17.5 %	66.6 %	66.6 %
99	Room Air Conditioning	Active	0.7 %	2.8 %	53.3 %	43.2 %	0.0 %	11.9 %

Net Savings Factors

Measures

RFRESFZP	Energy star freezer
CKLESWRP	Energy Star washer
RFRESRRP	Energy star refrigerator
ACEESARP	Energy Star room AC
ACEDEHUM	Dehumidifier
RFRESRT3	Energy Star CEE Tier 3 refrigerator, incremental c
RFRESRT2	CEE Tier 2 refrigerator, incremental cost
CKLC2WRP	Energy Star clothes washer CEE Tier 2
CKLC3WRP	Energy Star clothes washer CEE Tier 3

CKLESDRY	Efficient Clothes Dryer
CKLESETA	2014 Emerging Technology Award
EQPTVSBR	ENERGY STAR Sound Bars
ACEESRAC	ENERGY STAR Room Air Cleaners
ACEDHUME	Residential dehumidifier ENERGY STAR Most Efficient tier

Tracks [Base Track]

6032EPEP [is base track]	Efficient Products - Residential

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Efficient Products - Residential	6032EPEP	RFRESFZP	0.67	1.33
Efficient Products - Residential	6032EPEP	CKLESWRP	0.50	1.00
Efficient Products - Residential	6032EPEP	RFRESRRP	0.50	1.00
Efficient Products - Residential	6032EPEP	ACEESARP	0.67	1.33
Efficient Products - Residential	6032EPEP	ACEDEHUM	0.77	1.00
Efficient Products - Residential	6032EPEP	RFRESRT3	1.00	1.00
Efficient Products - Residential	6032EPEP	RFRESRT2	0.90	1.00
Efficient Products - Residential	6032EPEP	CKLC2WRP	0.50	1.00
Efficient Products - Residential	6032EPEP	CKLC3WRP	0.90	1.10
Efficient Products - Residential	6032EPEP	CKLESDRY	0.90	1.10
Efficient Products - Residential	6032EPEP	CKLESETA	1.00	1.20
Efficient Products - Residential	6032EPEP	EQPTVSBR	0.90	1.10
Efficient Products - Residential	6032EPEP	ACEESRAC	0.95	1.05
Efficient Products - Residential	6032EPEP	ACEDHUME	0.95	1.05

Lifetimes

The measure lifetime for each product is provided in the table below. Analysis period is the same as the lifetime.

Product	Measure Life
Sound Bars	4.4 years[13]
Freezers	17 years[14]
Refrigerators	17 years[14]
Clothes Dryers	12 years[15]
Clothes Washers	14 years[16]
Room Air Cleaners	9 years[17]
Room Air Conditioners	9 years[18]
Dehumidifiers	12 years[19]

Persistence

The persistence factor is assumed to be one.

Measure Cost

The per-unit incremental cost for each product is provided in the table below.

Product	Incremental Cost
Sound Bars	$0
ENERGY STAR Freezers (Upright)[20]	$12.14
ENERGY STAR Freezers (Chest)	$6.62
ENERGY STAR Freezers (Unknown Type)[21]	$8.65
ENERGY STAR/CEE Tier 1 Refrigerators[22]	$11
CEE Tier 2 Refrigerators	$20

CEE Tier 3 Refrigerators	$59
ENERGY STAR Clothes Dryers (Gas and Electric)[23]	$61
2014 Emerging Technology Award Clothes Dryers	$412
ENERGY STAR Clothes Washers[24]	$124
ENERGY STAR CEE Tier 2 Clothes Washers	$170
CEE Advanced Tier Clothes Washers	$179
Room Air Cleaners[25]	$56
Room Air Conditioners[26]	$50
ENERGY STAR Dehumidifiers[27]	$9.52
ENERGY STAR Most Efficient Dehumidifiers[28]	$75

Footnotes

[1] Baseline electric energy consumption based on information from a 2014 Fraunhofer Center for Sustainable Energy System study titled "Energy Consumption of Consumer Electronics in US Households." See file EPA RPP Analysis_EVT_2017.xlsx for baseline efficiency calculation. Due to the high market penetration of ENERGY STAR certified soundbars, a weighted average of the unit energy consumption of both non-ENERGY STAR (20% of market) and ENERGY STAR (80% of market) models was calculated to accurately provide savings estimates for the market.

[2] This measure assumes a more stringent requirement than ENERGY STAR Version 3.0. The more stringent requirement was developed by decreasing the power requirements and increasing the efficiency requirement by 50%. See file EPA RPP Analysis_EVT_2017.xlsx for assumptions included in high efficiency requirement.

[3] Although the 2014 Emerging Technology Award criteria are the basis for program eligibility, the actual performance measurements from the 11/3/2014 list of 2014 Emerging Technology Award Winning Dryers are used for characterizing the measure savings for the ventless Whirlpool and the vented LG award winning dryer models.

[4] The Summer and Winter Coincident kW are calculated using an algorithm for the kW during any hour (or group of hours) from the California study; Cadmus Group; "Residential Retrofit High Impact Measure Evaluation Report", Feb 8, 2010. To calculate an Equivalent Full Load Hours the UEC (* PartUse) is divided by the summer coincident kW (956 * .779)/0.088 = 8477 hours. The summer coincidence factor is therefore assumed to be 1.0 and a winter coincidence factor calculated as the relative winter to summer kW result from the algorithm. For the calculation see "Refrigerator kW Calculations.xls".

[5] Weighted average of 322 clothes washer cycles per year based on the Efficiency Vermont 2014 Technical Resource Manual clothes washer measure characterization. Federal standard employs a 0.91 field use factor, based on RECS 2009 survey data suggesting not all clothes washer loads are dried, but in earlier proceedings DOE references a higher percentage (0.96) for households with a dryer. A field evaluation completed by NEEA in 50 homes in the Northwest found a higher number of annual dryer cycles (337) than currently represented in the RECS data, noting users may not have consolidated their loads to the extent EPA assumed and were doing a significant percentage of "touch up" loads. Approximately one hour per cycle based on the ENERGY STAR clothes dryer qualified product list as of 9/15/2014. http://www.energystar.gov/sites/default/files/specs//ENERGY%20STAR%20Dryer%20Specification%20NEEA%20Amended%20comments%20Mar%2026%202013.pdf. Page 7.

[6] Based on 16 hours of use per day, 365 days per year

[7] Equivalent full load hours for Burlington, VT from RLW Report: Final Report Coincidence Factor Study Residential Room Air Conditioners, June 23, 2008 (http://www.puc.nh.gov/Electric/Monitoring%20and%20Evaluation%20Reports/National%20Grid/117_RLW_CF%20Res%20RAC.pdf)

[8] Based on 68 days of 24 hour operation; ENERGY STAR Dehumidifier Calculator http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/appliance_calculator.xlsx?f3f7-6a8b&f3f7-6a8b

[9] See file EPA RPP Analysis_EVT_2017.xlsx for kWh consumption and savings values for sound bars, freezers, room air cleaners, and room air conditioners. See ENERGY STAR Clothes Dryer, Efficient Clothes Washers, Energy Efficient Refrigerators, and ENERGY STAR Dehumidifiers measures under Efficient Products program for savings algorithms and assumptions pertaining to those technologies.

[10] Savings for unknown freezer type are based on a weighted average of upright freezers (36.74% market share) and chest freezers (63.26% of market share).

[11] See ENERGY STAR Clothes Dryer measure under Efficient Products program for fossil fuel savings analysis.

[12] See Efficient Clothes Washers measure under Efficient Products program for fossil fuel savings analysis.

[13] Sound bar lifetime is lifetime for video and compact audio products from Ecos. "Market Analysis for Standby Power." Report to Natural Resources Canada, 2008.

[14] Lifetime for freezers and refrigerators is the mean value from Figure 8.2.3, DOE, 2011-08-23 Technical Support Document for Energy Conservation Standards for Residential Refrigerators, Refrigerator-Freezers, and Freezers: https://www1.eere.energy.gov/buildings/appliance_standards/pdfs/refrig_finalrule_tsd.pdf

[15] Based on average lifetime in DOE Buildings Data Book http://buildingsdatabook.eren.doe.gov/TableView.aspx?table=5.7.15

[16] Based on DOE Life-Cycle Cost and Payback Period Excel-based analytical tool, available online at: http://www1.eere.energy.gov/buildings/appliance_standards/residential/docs/rcw_dfr_lcc_standard.xlsm.

[17] Room air cleaner lifetime from ENERGY STAR based on the following LBNL. "2008 Status Report - Savings Estimates for the ENERGY STAR Voluntary Labeling Program," 2007: https://buildings.lbl.gov/sites/all/files/lbnl-563802008.pdf

[18] Room air conditioner lifetime from ENERGY STAR, based on Appliance Magazine - Market Research The U.S. Appliance Industry: Market Value, Life Expectancy & Replacement Picture 2013 (Dec. 2013).

[19] Dehumidifier lifetime from ENERGY STAR Dehumidifier Calculator http://www.energystar.gov/ia/business/bulk_purchasing/bpsavings_calc/appliance_calculator.xlsx?f3f7-6a8b&f3f7-6a8b

[20] Freezer costs are based on the Freezer TSD Life-Cycle Cost and Payback Analysis "EERE-2008-BT-STD-0012-0128.pdf" found in Table 8.2.7 Standard-Size Freezers: Average Consumer Cost in 2014

[21] Average of costs for upright and chest freezers.

[22] Refrigerator configurations weighted according to table under Energy Savings. Values inflated 8.9% from 2009 dollars to 2015. Table 8.1.1, DOE, 2011-08-23 Technical Support Document for Energy Conservation Standards for Residential Refrigerators, Refrigerator-Freezers, and Freezers: https://www1.eere.energy.gov/buildings/appliance_standards/pdfs/refrig_finalrule_tsd.pdf

[23] For clothes dryer costs, see 2016 Clothes Dryer Analysis with HVAC Impact.xlsx. Based on DOE Life-Cycle Cost and Payback Period analysis Table 8.3.1, http://www.regulations.gov/contentStreamer?objectId=0900006480c8ee12&disposition=attachment&contentType=pdf

[24] Clothes washer costs based on inflating cost data from Life-Cycle Cost and Payback Period Excel-based analytical tool,. See '2018 Clothes Washer Analysis.xls' for details.

[25] From EPA.

[26] Room air conditioner cost from EPA Life Cycle Cost Estimate for ENERGY STAR Qualified Room Air Conditioner(s), based on average retail price of a qualified model in 2008 from national retail data.

[27] Based on incremental costs from 2016 ENERGY STAR Appliance Calculator. Refer to weighted average calculation on Savings Calc tab of ENERGY STAR Dehumidifier V6 EVT TRM Analysis.xlsx.

[28] DOE Energy Conservation Standards for Residential Dehumidifiers, Appliance and Equipment Standard, 10 CFR Part 430, July 23, 2012, page 73. The sourced table is an analysis on the incremental manufacturer production costs on dehumidifiers with varying incentive levels. Assuming the markup costs between the baseline units and the most efficient units are equal. The final incremental cost reproduced above is a straight average of all the dehumidifiers, both stand alone and whole house, with an efficiency level meeting or exceeding ENERGY STAR's Most Efficient criteria. Opted to combine the incremental cost into one value because the stand alone and whole house incremental costs were near idential.

Energy Efficient Refrigerators

Measure Number: IV-B-1 k
Portfolio: 94
Status: Active
Effective Date: 2016/1/1
End Date: [None]
Program: Efficient Products Program
End Use: Refrigeration

Update Summary

Split measure savings assumption in to pre-1993 and 1993-2001 bins so that savings can be claimed based on age of the equipment. Also included an unknown if date of manufacture is unknown.

Also added a midlife baseline shift calculation for early replacement measures.

Applicable Markets

Multifamily
Efficient Products
Low Income Single Family
Residential New Construction
Existing Homes

Referenced Documents

- 2009 VT Appliance Data_TRMCostAnalysis
- Refrigerator kW Calculations
- Refrigerator Standards and Savings 2014
- 2016 Refrigerator Retrofit Savings

Description

A refrigerator meeting either Energy Star/CEE Tier 1 specifications or the higher efficiency specifications of a CEE Tier 2, or CEE Tier 3 rated refrigerator is installed instead of a new unit of baseline efficiency. The measure applies to market opportunity and early replacement programs.

Algorithms

Electric Demand Savings

ΔkW = ΔkWh / Hours

Symbol Table

Electric Energy Savings

ΔkWh (Market Opportunity) $= kWh_{base} - (kWh_{base} \times (1\text{-}\%Savings))$

ΔkWh (Early Replacement - 1st six years) $= kWh_{baseOLD} - (kWh_{base} \times (1\text{-}\%Savings))$

ΔkWh (Early Replacement - Remaining Life) $= kWh_{base} - (kWh_{base} \times (1\text{-}\%Savings))$

Where:

$kWh_{baseOLD}$ = Assumed consumption of existing unit being replaced

Age group	$kWh_{baseOLD}$ (kWh/yr)
Pre 1993	1192.5[1]
1993-2001	750 [2]

Unknown	898 [3]

%Savings = Specification of energy consumption below Federal Standard:

Tier	%Savings
Energy Star and CEE Tier 1	10%
Energy Star Most Efficient and CEE Tier 2	15%
CEE Tier 3	20%

ΔkW = Gross customer connected load kW savings for the measure

ΔkWh (Early Replacement - 1st six years) = Gross customer annual kWh savings for Early Replacement, remaining life of existing unit (1st six years)

ΔkWh (Early Replacement - Remaining Life) = Gross customer annual kWh savings for Early Replacement, remaining measure life

ΔkWh (Market Opportunity) = Gross customer annual kWh savings for Market Opportunity

Hours = Equivalent Full Load Hours

8477

kWh_{base} = Baseline consumption, assuming 22.5 ft^3 adjusted volume

Configuration	Market Weight	kWh_{base}
Top Freezer (PC 3)	52%	516
Bottom Freezer (PC 5)	13%	684
Bottom Freezer w/ TTD (PC 5A)	13%	625
Side-by-Side w/ TTD (PC 7)	22%	574

Mid Life Savings Adjustment

For early replacement measures the following table provides the appropriate midlife adjustment to be applied:

Tier	Age group of replaced unit	DkWh Early Replacement, 1st six years	DkWh remaining life of ER	Midlife Adjustment
Energy Star/CEE Tier 1	Pre 1993	659.6	59.2	9.0%
	1993-2001	217.1	59.2	27.3%
CEE Tier 2	Pre 1993	689.2	88.8	12.9%
	1993-2001	246.7	88.8	36.0%
CEE Tier 3	Pre 1993	718.8	118.4	16.5%
	1993-2001	276.3	118.4	42.9%

Baseline Efficiencies

Baseline Efficiencies – New

Baseline efficiency is a new refrigerator meeting the minimum federal efficiency standard for refrigerators effective September 15th, 2014.

Baseline Efficiencies – Retrofit

Baseline efficiency for the first six years is an existing refrigerator. Savings are provided for units that are older than 1993, those that are from 1993-2001 and those that are unknown. After that the baseline is a new refrigerator meeting the minimum federal efficiency standard for refrigerators effective September 15th, 2014.

High Efficiency

The High Efficiency level is a refrigerator meeting Energy Star specifications for efficiency effective September 15th, 2014 (10% above federal standard), a refrigerator meeting CEE Tier 2 specifications (15% above federal standard), or meeting CEE Tier 3 specifications (20% above federal standards).

Load Shapes

4b Residential Refrigerator

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
4	Residential Refrigerator	Active	30.8 %	33.0 %	17.1 %	19.1 %	79.6 %	100.0 %

Net Savings Factors

Measures

RFRESRRP	Energy star refrigerator
RFRESRER	Energy star refrigerator, early replacement
RFRESRT3	Energy Star CEE Tier 3 refrigerator, incremental c
RFRESRT2	CEE Tier 2 refrigerator, incremental cost
RFRT2RER	CEE Tier 2 Refrigerator, Early Replacement
RFRT3RER	CEE Tier 3 Refrigerator, Early Replacement

Tracks [Base Track]

6032EPEP [is base track]	Efficient Products - Residential
6034LISF [is base track]	LISF Retrofit
6038VESH [is base track]	RNC VESH
6017CUST [is base track]	6017CUST
6020PRES [is base track]	6020PRES

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Efficient Products - Residential	6032EPEP	RFRESRRP	0.50	1.00
Efficient Products - Residential	6032EPEP	RFRESRT3	1.00	1.00
Efficient Products - Residential	6032EPEP	RFRESRT2	0.90	1.00
LISF Retrofit	6034LISF	RFRESRER	1.00	1.00
LISF Retrofit	6034LISF	RFRT2RER	1.00	1.00
LISF Retrofit	6034LISF	RFRT3RER	1.00	1.00
RNC VESH	6038VESH	RFRESRRP	0.50	1.00
RNC VESH	6038VESH	RFRESRT3	1.00	1.00
RNC VESH	6038VESH	RFRESRT2	0.90	1.00
6017CUST	6017CUST	RFRESRRP	1.00	1.00
6017CUST	6017CUST	RFRESRER	1.00	1.00
6017CUST	6017CUST	RFRESRT3	1.00	1.00
6017CUST	6017CUST	RFRESRT2	1.00	1.00
6017CUST	6017CUST	RFRT2RER	1.00	1.00
6017CUST	6017CUST	RFRT3RER	1.00	1.00
6020PRES	6020PRES	RFRESRRP	0.90	1.00
6020PRES	6020PRES	RFRESRER	0.90	1.00
6020PRES	6020PRES	RFRESRT3	0.90	1.00
6020PRES	6020PRES	RFRESRT2	0.90	1.00
6020PRES	6020PRES	RFRT2RER	0.90	1.00
6020PRES	6020PRES	RFRT3RER	0.90	1.00

Persistence

The persistence factor is assumed to be one.

Lifetimes

17 years

For early replacement, the remaining useful life of the existing unit is assumed to be 6 years.

Analysis period is the same as the lifetime.

Measure Cost

The full cost of a baseline unit is $742.

The incremental cost to the Energy Star level is $11, to CEE Tier 2 level is $20 and to CEE Tier 3 is $59.

For early replacement measures the full cost of the installed efficient unit will be used, i.e. $753 for ENERGY STAR, $762 for CEE Tier 2 and $801 for CEE Tier 3.

Prescriptive Savings Tables

ΔkW resulting deemed savings:

Tier	Age group of replaced unit	ΔkW Early Replacement, 1	ΔkW MOP and remaining life of ER
Energy Star/CEE Tier 1	Pre 1993	0.0778	0.007
	1993-2001	0.0256	0.007
	Unknown	0.0431	0.007
CEE Tier 2	Pre 1993	0.0813	0.0105
	1993-2001	0.0291	0.0105
	Unknown	0.0466	0.0105
CEE Tier 3	Pre 1993	0.848	0.014
	1993-2001	0.326	0.014
	Unknown	0.0501	0.014

ΔkWh resulting deemed savings:

Tier	Age group of replaced unit	ΔkWh Early Replacement, 1	ΔkWh MOP and remaining life of ER
Energy Star/CEE Tier 1	Pre 1993	660	59
	1993-2001	217	59
	Unknown	365	59
CEE Tier 2	Pre 1993	689	89
	1993-2001	247	89
	Unknown	395	89
CEE Tier 3	Pre 1993	719	118
	1993-2001	276	118
	Unknown	424	118

Footnotes

[1] Based on custom data using model numbers collected by Efficiency Vermont in 2008-2009 before measure became prescriptive.

[2] Based on AHAM efficiency by age data.

[3] Based on weatherization agency data on age of refrigerators replaced through their programs. See 2016 Refrigerator Retrofit Savings.xls for details.

Refrigerator/Freezer Early Retirement

Measure Number:	IV-B-3 c
Portfolio:	EVT TRM Portfolio 2017-10
Status:	Active
Effective Date:	2018/1/1
End Date:	[None]
Program:	Efficient Products Program
End Use:	Refrigeration

Update Summary

Savings from early retirement of refrigerators and freezers has been recalculated using the last year of data from the EVT program (2015) and using an updated IL regression model.

This measure combines the following characterizations in to one measure:

EP: Freezer Early Removal

EH: Refrigerator Early Removal and Freezer Early Removal

LI: Refrigerator Early Removal and Freezer Early Removal

MF: Refrigerator Early Removal and Freezer Early Removal

Applicable markets

Efficient Products
Multi Family
Existing Homes
Low Income Single Family

Referenced Documents

- Refrigerator kW Calculations
- KEMA_RARP_report_to_SCE_040726
- FinalResidentialRetroEvaluationReport_11
- Refrig Freezer Retirement Analysis_2018
- Appliance Recycling Update no single door

Description

This is an early retirement measure for the removal of an existing inefficient secondary refrigerator or freezer from service either through a curbside pick up program or when a suitable unit is removed during a house visit. The program will target refrigerators with an age greater than 10 years, though data from units removed through the program suggests the average age of retired units is over 25 years. Savings are calculated for the estimated energy consumption during the assumed remaining life of the unit.

Baseline Efficiencies

The existing refrigerator baseline consumption is based upon data collected by Jaco from units retired in the last EVT program 2015.

High Efficiency

N/A

Algorithms

Electric Demand Savings

$\Delta kW = \Delta kWh / Hours$

Symbol Table

Electric Energy Savings

$\Delta kWh = UEC \times PartUse \times HF$

Where:

ΔkW = gross customer connected load kW savings for the measure

ΔkWh = gross customer annual kWh savings for the measure

HF = Household Factor, to adjust savings based on the household type from which unit is removed.

= 84% for low income[2], 72% for multi family[3] , 1.0 for all others

Hours = Equivalent Full Load Hours

= 8477[1]

PartUse = Part use adjustment factor to account for average use of appliance through the year [4]

Unit Type	PartUse
Refrigerator	99.6%
Freezer	99.8%

UEC = Unit Energy Consumption of the retired unit[5]

Unit Type	UEC (kWh)
Refrigerator	746
Freezer	825

Load Shapes

4b Residential Refrigerator

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
4	Residential Refrigerator	Active	30.8 %	33.0 %	17.1 %	19.1 %	79.6 %	100.0 %

Net Savings Factors

Measures

RFRRERPS	Refrigerator early retirement program, secondary

Tracks [Base Track]

6032EPEP [is base track]	Efficient Products - Residential

Persistence

The persistence factor is assumed to be one.

Lifetimes

8 years[6]

Analysis period is the same as the lifetime.

Measure Cost

The cost of the administrative, pickup and recycling of the refrigerator is $110 based upon cost provided by Jaco during previous program.

O&M Cost Adjustments

There are no operation and maintenance cost adjustments for this measure.

Reference Tables

Prescriptive savings are provided below:

Unit Type	Reporting Category	Algorithm	kWh savings	kW savings
	Low Income	746 * 0.996 * 0.84	624	0.074

Refrigerator	Multi family	746 * 0.996 * 0.72	535	0.063
	All other (Efficient Products and Existing Homes)	746 * 0.996 * 1.0	743	0.088
Freezer	Low Income	825 * 0.998 * 0.84	692	0.082
	Multi family	825 * 0.998 * 0.72	593	0.070
	All other (Efficient Products and Existing Homes)	825 * 0.998 * 1.0	823	0.097

Footnotes

[1] Consistent with other Residential Refrigerator measures and based on the ratio of UEC to kW, calculated using an algorithm for the kW during any hour (or group of hours) from the California study; Cadmus Group; "Residential Retrofit High Impact Measure Evaluation Report", Feb 8, 2010. For the calculation see “Refrigerator kW Calculations.xls”.

[2] Size Factor is calculated by comparing the average Low Income retrofitted energy savings per unit (592kwh for ENERGY STAR and 620 for CEE T2) to the average single family residential retrofitted energy savings (709kWh for ENERGY STAR and 737 for CEE T2) indicating a 84% savings factor.

[3] Size Factor is calculated by comparing the average MF retrofitted energy savings per unit (525kwh) to the average single family residential retrofitted energy savings (726kWh) indicating a 72% savings factor.

[4] Based on analysis of Jaco data for program year 2015. Participants were asked how much the refrigerator was run through the year and the average result divded by 12 months.

[5] Unit Energy Consumption is based upon review of the data collected by Jaco from units retired during the last year of the program 2015. To estimate the consumption of the retired units EVT applied results from this program data in a regression equation performed in a recent Cadmus Illinois evaluation (equation coefficients provided in a July 30 memo from Cadmus: "Appliance Recycling Update no single door"). See "Refrig Freezer Retirement Analysis_2018.xlsx".

[6] KEMA “Residential refrigerator recycling ninth year retention study”, 2004, page 3-1.

Low-E Storm Window

Measure Number: IV-K-1 a
Portfolio: EVT TRM Portfolio 2017-04
Status: Active
Effective Date: 2017/1/1
End Date: [None]
Program: Efficient Products Program
End Use: Shell

Update Summary

Referenced Documents

- VT SF Existing Homes Onsite Report_final 021513
- Fannie Mae APPENDIX F ESTIMATED USEFUL LIFE TABLES 10/2014
- low_e storm window analysis 2016
- efficiency-vermont-low-e-and-behold-white-paper
- Properties of Low-E Storm Windows and Panels_PNNL_24444
- NEST VEIC Data Share 9Jun2017

Description

Low emissivity (Low-E) glass is formed by adding an ultra-thin layer of metal to clear glass. The metallic-oxide (pyrolytic) coating is applied when the glass is in its molten state, and the coating becomes a permanent and extremely durable part of the glass. This coating is also known as "hard-coat" Low-E.

Low-E glass is designed to redirect heat back towards the source, effectively providing higher insulating properties and lower solar heat gain as compared to traditional clear glass. This characterization captures the savings associated with installing low-e storm windows to an existing window assembly (retrofit) or as a market opportunity whereby a low-e storm window is installed instead of a traditional storm window with clear glazing.

This characterization outlines the methodology used to claim savings for EVT’s mid-stream incentive program, which takes a deemed approach to savings. Energy savings for this program are blended based on proportions of primary heating sources for Vermont homes, are claimed on a per window basis considering window dimensions, and assume a 20/80 split of retrofit/MOP savings, respectively[1].

Market opportunity savings consider performance differences related to the insulating properties of window assemblies and their tansmittance of solar energy. Retrofit savings consider the same performance differences with the additional benefit of improved airsealing.

Baseline Efficiencies

EVT’s mid-stream incentive program for exterior low-e storm windows deems that 20% of installations are retrofits and 80% are Market Opportunity[1].

In the Retrofit (RET) scenario, the baseline condition is the existing window assembly.

In the Market Opportunity (MOP) scenario, the baseline condition is an exterior storm window with clear glazing.

Efficient Equipment

The efficient condition is the installation of exterior storm window with low-e coated glazing.

Algorithms

Electric Demand Savings

ΔkW	$= \Delta kWh_{TOT} / FLH$

For the EVT mid-stream incentive program, the resulting savings from the 20/80 retrofit/market opportunity blend are:

Width (in.)	Height (in.)	Heating Season kW savings
24	39	0.00024
28	39	0.00028
28	47	0.00034
28	55	0.00039
32	39	0.00032
32	47	0.00038
32	55	0.00045
32	63	0.00051

36	39	0.00036
36	47	0.00043
36	55	0.00050

Symbol Table

Electric Energy Savings

Savings for the upsteam program are calculated as follows:

$$\Delta kWh_{TOT} = (\Delta kWh_{MOP} \times \%_{MOP}) + (\Delta kWh_{RET} \times \%_{RET})$$

The resulting kWh savings for standard window sizes included in the program are:

Width (in.)	Height (in.)	Heating Season kWh savings
24	39	0.2
28	39	0.2
28	47	0.3
28	55	0.3
32	39	0.3
32	47	0.3
32	55	0.4
32	63	0.4
36	39	0.3
36	47	0.4
36	55	0.4

The following algorithms illustrate the considerations for market opportunity and retrofit savings portions, respectively.

Symbol Table

Electric Energy Savings (Market Opportunity)

$$\Delta kWh_{MOP} = Load_{elec} \times (((U_{clear} - U_{low\text{-}e}) \times HDH) - (I \times \%_{incidence} \times (SHGC_{clear} - SHGC_{low\text{-}e}))) \times A_{window} / (\eta_{elec\ heat} \times 3412)$$

Symbol Table

Electric Energy Savings (Retrofit)

$$\Delta kWh_{RET} = Load_{elec} \times (((U_{exist} - U_{low\text{-}e}) \times HDH) - (I \times \%_{incidence} \times (SHGC_{exist} - SHGC_{low\text{-}e})) + (Leak_{exist} - Leak_{low\text{-}e})) \times A_{window} / (\eta_{elec\ heat} \times 3412)$$

Symbol Table

Fossil Fuel Savings

Savings for the upsteam program are calculated as follows:

$$\Delta MMBtu_{TOT} = (\Delta MMBtu_{MOP} \times \%_{MOP}) + (\Delta MMBtu_{RET} \times \%_{RET})$$

The resulting MMBtu savings (by fuel type) for standard window sizes included in the program are shown in the following table. Note: the savings claim for each window will include savings from all fuel types.

Width (in.)	Height (in.)	Fuel Oil	Natural Gas	Propane	Wood
24	39	0.041	0.016	0.012	0.013
28	39	0.048	0.019	0.014	0.015
28	47	0.058	0.023	0.016	0.018
28	55	0.068	0.027	0.019	0.021
32	39	0.055	0.022	0.016	0.017
32	47	0.066	0.026	0.019	0.020
32	55	0.077	0.031	0.022	0.024
32	63	0.089	0.035	0.025	0.027
36	39	0.062	0.024	0.018	0.019
36	47	0.074	0.029	0.021	0.023
36	55	0.087	0.034	0.025	0.027

The following algorithms illustrate the considerations for market opportunity and retrofit savings portions, respectively.

Symbol Table

Fossil Fuel Savings (Market Opportunity)

Savings for each fuel type are expressed by the following algorithm:

$$\Delta MMBtu_{MOP} = Load_{fossil} \times (((U_{clear} - U_{low\text{-}e}) \times HDH) - (I \times \%_{incidence} \times (SHGC_{clear} - SHGC_{low\text{-}e}))) \times A_{window} / (\eta_{fossil\ heat} \times 1{,}000{,}000)$$

Symbol Table

Fossil Fuel Savings (Retrofit)

Savings for each fuel type are expressed by the following algorithm:

$$\Delta MMBtu_{RET} = Load_{fossil} \times (((U_{exist} - U_{low\text{-}e}) \times HDH) - (I \times \%_{incidence} \times (SHGC_{exist} - SHGC_{low\text{-}e})) + (Leak_{exist} - Leak_{low\text{-}e})) \times A_{window} / (\eta_{fossil\ heat} \times 1{,}000{,}000)$$

Where:

$\%_{incidence}$ = Incidence factor, expressed in percentage, describing how much insolation actually hits a window.

=25%[2]

$\%_{MOP}$ = For the midstream program, the percentage of installations assumed to be market opportunities.

=80%[1]

$\%_{RET}$ = For the midstream program, the percentage of installations assumed to be retrofits.

=20%[1]

ΔkW = Gross customer connected load kW savings for the measure (kW).

ΔkWh_{MOP} = Gross annual market opportunity kWh savings for the measure (kWh).

ΔkWh_{RET} = Gross annual retrofit kWh savings for the measure (kWh).

ΔkWh_{TOT} = Gross annual kWh savings for the measure (kWh).

$\Delta MMBtu_{MOP}$ = Gross annual market opportunity MMBtu savings for the measure (MMBtu).

$\Delta MMBtu_{RET}$ = Gross annual retrofit MMBtu savings for the measure (MMBtu).

$\Delta MMBtu_{TOT}$ = Gross annual MMBtu savings for the measure (MMBtu).

$\eta_{elec\ heat}$ = Efficiency of electric heating system, in COP.

=1.0[3]

$\eta_{fossil\ heat}$ = Efficiency of heating system, in AFUE, based on fossil fuel type:

Fuel Type	**AFUE**[3]
Fuel Oil	0.842
Nat. Gas	0.878
Propane	0.874
Wood	0.650

1,000,000 = Conversion factor from Btu to MMBtu.

3412 = Conversion factor from Btu to kWh.

A_{window} = Area of storm window, including visible framing and glazing (ft^2)

The following table shows window area for the common window dimensions included in the upstream program:

Width (in.)	Height (in.)	A_{window}
24	39	6.50
28	39	7.58
28	47	9.14
28	55	10.69
32	39	8.67
32	47	10.44
32	55	12.22
36	39	9.75
36	47	11.75
36	55	13.75

FLH = Full Load Hours for heating, as defined by loadshape #5: Residential Space Heat.

=841

HDH = Annual Heating Degree Hours (°F.h)

=129,935 (°F.h)[4]

I = Total unobstructed heating season insolation on a vertical surface (Btu/ft^2)

=155,037.85 (Btu/ft^2) [5]

$Leak_{exist}$ = Heating load (Btu/ft^2) due to air infiltration through the existing window assembly.

= 16,996.6 (Btu/ft^2)[8]

$Leak_{low\text{-}e}$ = Heating load (Btu/ft^2) due to air infiltration through the window assembly after installation of the low-e storm window.

= 4,798.3 (Btu/ft^2)[8]

$Load_{elec}$ = Percentage of annual heating load contributed by electric source.

= 1%[6]

$Load_{fossil}$ = Percentage of annual heating load contributed by fossil fuel source, as indicated by the following table:

Fuel Type	**Load**[3]
Fuel Oil	0.51
Nat. Gas	0.21
Propane	0.15
Wood	0.12

$SHGC_{clear}$ = Solar Heat Gain Coefficient for the clear glazing baseline assembly, representing the percentage of incident insolation that passes through the glazing and into the home.

=0.493[7]

$SHGC_{exist}$ = Solar Heat Gain Coefficient for existing baseline assembly, representing the percentage of incident insolation that passes through the glazing and into the home.

=0.549[7]

$SHGC_{low\text{-}e}$ = Solar Heat Gain Coefficient for the efficient low-e glazing assembly, representing the percentage of incident insolation that passes through the glazing and into the home.

=0.425[7]

U_{clear} = U-factor value of the complete window assembly (existing window plus exterior storm window) for the baseline scenario that assumes a clear glass storm window. (Btu/ft^2.°F.h)

=0.329 (Btu/ft^2.°F.h)[7]

U_{exist} = U-factor value of the complete existing window assembly. (Btu/ft^2.°F.h)

=0.457 (Btu/ft^2.°F.h)[7]

$U_{low\text{-}e}$ = U-factor value of the complete window assembly (existing window plus exterior storm window) for the efficient scenario that assumes a low-e glass storm window. (Btu/ft^2.°F.h)

=0.269 (Btu/ft^2.°F.h)[7]

Load Shapes

5b Residential Space heat

Number	**Name**	**Status**	**Winter On kWh**	**Winter Off kWh**	**Summer On kWh**	**Summer Off kWh**	**Winter kW**	**Summer kW**
5	Residential Space heat	Active	42.9 %	57.1 %	0.0 %	0.0 %	25.0 %	0.0 %

Net Savings Factors

Measures

TSHWINDO	Window improvements

Tracks [Base Track]

6032EPEP [is base track]	Efficient Products - Residential

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Efficient Products - Residential	6032EPEP	TSHWINDO	1.00	1.00

Lifetimes

10 years[9]

Measure Cost

The incremental cost[10] of a low-e storm window is $1.13/ft^2$

For retrofit[11] a cost of $7.60/ft^2$ plus $11.00 per window for materials and labor is assumed.

For the EVT mid-stream incentive program, the resulting costs from the 20/80 retrofit/market opportunity blend are:

Width (in.)	Height (in.)	Blended Cost
24	39	$17.95
28	39	$20.57
28	47	$24.34
28	55	$28.11
32	39	$23.20
32	47	$27.51
32	55	$31.81
32	63	$36.12
36	39	$25.82
36	47	$30.67
36	55	$35.52

There are no operation and maintenance cost adjustments for this measure.

Footnotes

[1] During EVT's pilot promotional period in 2015 it was observed that sales of storm windows increased by about 38%. Market lift occurred and it is assumed that the lift in sales were installed as retrofit applications. Based on this assumption, about 27% of sales would otherwise be claimed as retrofit, however 20% is assumed for the savings claim until additional survey data is available to better substantiate the number of purchases that are eligible to claim retrofit savings. See reference document "efficiency-vermont-low-e-and-behold-white-paper.pdf" for additional details.

[2] Professional judgement to account for shading due to trees, natural terrain, architecture, and the use of blinds by occupants.

[3] Vermont Existing Homes Onsite Report, February 2013

[4] Calculated from TMY3 data for Burlington, VT, assuming a base temperature of 58°F and a heating season that runs from September 19th to May 6th. See worksheet "Heating Degree Hours" in reference file "low_e storm window analysis 2016.06.03.xlsx" for complete derivation.

[5] Based on Energy3D modeling software dataset for Boston, deemed an appropriate representation for Vermont. See worksheet "Vertical Insolation" in reference file "low_e storm window analysis 2016.06.03.xlsx" for complete derivation. Value is blended to represent the average for a vertical surface of any orientation.

[6] Blended fuel savings use the Vermont Existing Homes Onsite Report, February 2013 as a basis.

[7] Weighted average based on statewide window area by type as reported Vermont Existing Homes Onsite Report, February 2013 and SHGCs published in Pacific Northwest National Laboratory publication PNLL-24444. See worksheet "Deemed Window Properties MOP" in reference file "low_e storm window analysis 2016.06.03.xlsx" for details on derivation.

[8] Calculated from TMY3 data for Burlington, VT, assuming a base temperature of 58°F and a heating season that runs from September 19th to May 6th. Assumptions and full methodology can be found on worksheets "Leakage Rates" and "Deemed Window Properties RET" in reference file "low_e storm window analysis 2016.06.03.xlsx".

[9] Consistent with typical manufacturer warranties and the Effective Useful Life recognized by FannieMae.

[10] Based on the average buydown cost from the EVT mid-stream program, see low_e storm window analysis 206.06.03.xlsx, worksheet "Incremental Costs" for full derivation.

[11] Based on the average storm window cost from the EVT mid-stream program as well as considerations for labor and materials, see low_e storm window analysis 206.06.03.xlsx, worksheet "Incremental Costs" for full derivation.

Tank Wrap

Measure Number:	VII-A-1 c
Portfolio:	81
Status:	Inactive
Effective Date:	2013/1/1
End Date:	2018/12/31
Program:	Existing Homes
End Use:	Hot Water

Referenced Documents

1. Pennsylvania Public Utility Commission Technical Reference Manual (PA TRM)
2. NREL, National Residential Efficiency Measures Database
3. Efficiency Vermont Program Documentation
4. DOE, "Residential Heating Products Final Rule Technical Support Document"

Description

Insulation "blanket" is wrapped around the outside of an existing electric hot water tank to reduce stand-by losses.

Estimated Measure Impacts

Average Annual MWH Savings per unit	Average number of measures per year	Average Annual MWh savings per year
0.113	100	11.3

Algorithms

Electric Demand Savings

For the prescriptive assumption, the assumed savings is:

$\Delta kW = 113 / 8760$

$\Delta kW =$ **0.01289 kW**

ΔkW	= ΔkWh 8760

Symbol Table

Electric Energy Savings

For the prescriptive assumption, 40 gallons is selected as an average tank[1441], and the savings are derived from adding R-10 to an R-12 tank.

The prescriptive savings are therefore calculated as:

$\Delta kWh = ((23.18/12 – 25.31/22) * 55 * 8760) / (3412 * 0.98)$

$\Delta kWh =$ **113 kWh**

ΔkWh	$= ((U_{base}A_{base} – U_{insul}A_{insul}) \times \Delta T \times Hours) / (3412 \times \eta DHW)$

Where:

ΔkW	=	gross customer connected load kW savings for the measure
ΔkWh	=	gross customer annual kWh savings for the measure
ΔT	=	Average temperature difference between tank water and outside air temperature (°F) = 55°F[1436]
ηDHW	=	Recovery efficiency of electric hot water heater = 0.98[1437]
A_{base}	=	Surface area of storage tank prior to adding tank wrap (square feet) = 23.18[1438]
A_{insul}	=	Surface area of storage tank after addition of tank wrap (square feet)

		= 25.31[1438]
ΔkWh	=	kWh savings from tank wrap installation, calcualted below
3412	=	Conversion from BTU to kWh
8760	=	Number of hours in a year (savings are from reduced standby loss and are therefore assumed to be constant over the year).
Hours	=	Number of hours in a year (since savings are assumed to be constant over year). = 8760
U_{base}	=	Overall heat transfer coefficient prior to adding tank wrap (Btu/Hr-F-ft^2) = 1/12[1439]
U_{insul}	=	Overall heat transfer coefficient after addition of tank wrap (Btu/Hr-F-ft^2) = 1/22[1440]

Baseline Efficiencies

The baseline condition is a hot water tank that is not already well insulated. Newer, rigid, foam insulated tanks are considered to be effectively insulated while older tanks with fiberglass insulation that gives to gentle pressure are not.

High Efficiency

High efficiency is addition of R-10 insulation to hot water tank.

Operating Hours

8760, savings are from reduced standby loss and are therefore assumed to be constant over the year.

Load Shapes

25a Flat (8760 hours)

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
25	Flat (8760 hours)	Active	31.7 %	34.9 %	15.9 %	17.5 %	100.0 %	100.0 %

Net Savings Factors

Measures

HWEINSUL	Insulate hot water tank

Tracks [Base Track]

6036RETR [is base track]	Res Retrofit

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Res Retrofit	6036RETR	HWEINSUL	0.90	1.00

Persistence

The persistence factor is assumed to be one.

Lifetimes

6 years (same as in DPS screening of Efficiency Utility Core programs).

Analysis period is the same as the lifetime.

Measure Cost

$35 average retrofit cost.[1442]

O&M Cost Adjustments

N/A

Fossil Fuel Description

N/A

Footnotes

Pipe Wrap

Measure Number: **VII-A-2 d**
Portfolio: EVT TRM Portfolio 2017-08
Status: Active
Effective Date: 2017/1/1
End Date: [None]
Program: Existing Homes
End Use: Hot Water

Update Summary

Measure has been reviewed according to the 3-year reliability update cycle:

- Revised measure lifetime
- Revised measure cost to align with actual program cost
- Updated R-value of pipe wrap to reflect information from company that provides pipe wrap for EVT
- Updated fuel water heater efficiency

Referenced Documents

- Measures and Assumptions for DSM Planning Appendix C Substantiation Sheets
- DEER2014-EUL-table-update_2014-02-05.xlsx

Description

Insulation is added to both the hot and cold uninsulated pipes from the hot water tank to the first elbow. This is the most cost effective section to insulate since the water pipes act as an extension of the hot water tank up to the first elbow which acts as a heat trap. Insulating this length therefore helps reduce standby losses. This measure applies to retrofit direct install implementation at a residential location.

Algorithms

Electric Demand Savings

Using the default assumptions provided below, electric demand savings for homes with electric DHW systems are:

$\Delta kW = 24.9 / 8{,}760$

$= 0.00294$ kW

ΔkW $= \Delta kWh / 8{,}760$

Symbol Table

Electric Energy Savings

Using the default assumptions provided below, electric energy savings for homes with electric DHW systems are:

$\Delta kWh = (((0.131 / 1.0) – (0.327 / 3.2)) * 6 * 55 * 8{,}760) / 0.98 / 3{,}412$

$= 24.9$ kWh

ΔkWh $= ((C_{exist} / R_{exist} - C_{new} / R_{new}) \times L \times \Delta T \times 8{,}760) / \eta Electric\_DHW / 3{,}412$

Symbol Table

Fossil Fuel Description

Using the default assumptions provided below, fossil fuel savings for homes with fossil fuel DHW systems are:

$\Delta MMBtu = ((0.131 / 1) – (0.327 / 3.2)) * 6 * 55 * 8{,}760) / 0.78 / 1{,}000{,}000$

$= 0.107$ MMBtu

$\Delta MMBtu$ $= ((C_{exist} / R_{exist} - C_{new} / R_{new}) \times L \times \Delta T \times 8{,}760) / \eta Fuel\_DHW / 1{,}000{,}000$

Where:

ΔkW = Gross customer connected load kW savings for the measure

ΔkWh = Gross customer annual kWh savings for the measure

$\Delta MMBtu$ = Gross customer annual MMBtu savings for the measure

ΔT = Average temperature difference between supplied water and outside air temperature (°F). 55°F[1] ηElectric_DHW = Recovery efficiency of electric water heater

= 0.98[2]

ηFuel_DHW = Recovery efficiency of fuel water heater

0.78[5]

1,000,000 = Conversion factor from Btu to MMBtu

3,412 = Conversion factor from Btu to kWh

8,760 = Hours per year

C_{exist} = Circumference (ft) of uninsulated pipe

= Diameter (in) * π/12 = (for a 0.5" pipe, C_{exist} = 0.131ft; for a 0.75” pipe, C_{exist} = 0.196ft)

Assume a default of 0.131 ft for a 0.5" pipe

C_{new} = Circumference of insulated pipe (ft)

= Diameter (in) * π/12

Assuming 0.5” pipe and 3/8” foam ((0.5 + 3/8 + 3/8) * π/12)

= 0.327

L = Length of pipe from water heating source covered by pipe wrap (ft)

Assuming 3 feet of both the hot and cold pipes

= 6 ft

R_{exist} = Pipe heat loss coefficient of uninsulated pipe [(hr-°F-ft^2)/Btu]

= 1.0[3]

R_{new} = Pipe heat loss coefficient of insulated pipe (new) [(hr-°F-ft)/Btu]

= Actual (1.0 + R value of insulation)

Assuming R-2.2[4] (3/8” foam) insulation is added

= 3.2

Baseline Efficiencies

The baseline condition is an uninsulated, domestic hot or cold water pipe.

High Efficiency

The high efficiency condition is a domestic hot or cold water pipe with R-2.2 pipe wrap installed on the hot or cold water pipes up to the first elbow.

Load Shapes

7a Residential DHW insulation
53a Controlled DHW Insulation

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
7	Residential DHW insulation	Active	31.7 %	34.9 %	15.9 %	17.5 %	100.0 %	100.0 %
53	Controlled DHW Insulation	Active	31.7 %	34.9 %	15.9 %	17.5 %	51.0 %	59.4 %

Net Savings Factors

Measures

HWEPIPES	Insulate hot water pipes

Tracks [Base Track]

6034LISF [is base track]	LISF Retrofit
6036RETR [is base track]	Res Retrofit

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
LISF Retrofit	6034LISF	HWEPIPES	1.00	1.00
Res Retrofit	6036RETR	HWEPIPES	0.90	1.00

Persistence

The persistence factor is assumed to be one.

Lifetimes

12 years[6]

Analysis period is the same as the lifetime.

Measure Cost

The measure cost is the actual program cost (material and labor) of installing the pipe wrap: $2.00 per linear foot, or $12.00 for a 6 foot length.

O&M Cost Adjustments

There are no operation and maintenance cost adjustments for this measure.

Footnotes

[1] Assumes 120°F water leaving the hot water tank and average temperature of basement of 65°F.

[2] Review of AHRI database shows that electric water heaters have a recovery efficiency of 98%.

[3] Navigant, “Measures and Assumptions for Demand Side Management (DSM) Planning; Appendix C Substantiation Sheets”, April 2009, page 77.

[4] Program provides R-2.2 pipe wrap.

[5] Based on a review of fuel DHW systems available in AHRI database.

[6] Measure lifetime from California DEER. Average of values for electric DHW (13 years) and gas DHW (11 years). See file DEER2014-EUL-table-update_2014-02-05.xlsx.

Tank Temperature Turn-Down

Measure Number:	VII-A-3 c
Portfolio:	81
Status:	Inactive
Effective Date:	2013/1/1
End Date:	2018/12/31
Program:	Existing Homes
End Use:	Hot Water

Referenced Documents

1. Pennsylvania Public Utility Commission Technical Reference Manual (PA TRM).
2. NREL, National Residential Efficiency Measures Database
3. DOE, "Residential Heating Products Final Rule Technical Support Document," Table 3.2.13, http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/htgp_finalrule_ch3.pdf

- DHWConsSavingsWHEC10-12

Description

The domestic hot water tank thermostat is lowered to reduce standby losses.

Estimated Measure Impacts

Algorithms

Electric Demand Savings

Defaults:

$\Delta kW = 45.5 / 8760$

$= 0.00519$ kW

ΔkW	$= \Delta kWh / 8760$

Symbol Table

Electric Energy Savings

Defaults:

$\Delta kWh = ((1/20 * 23.18) * 15 * 8760) / (3412 * 0.98)$

$= 45.5$ kWh

For electric DHW systems:

ΔkWh	$= ((U_{base} \times A_{base}) \times \Delta T \times Hours) / (3412 \times \eta DHW)$

Symbol Table

Fossil Fuel Savings

Defaults:

$\Delta MMBtu\ \Delta = ((1/20 * 23.18) * 15 * 8760) / (1{,}000{,}000 * 0.76)$

$= 0.20$ MMBtu

For fossil fuel DHW systems:

ΔMMBtu	$= ((U_{base} \times A_{base}) \times \Delta T \times Hours) / (1{,}000{,}000 \times \eta DHW)$

Where:

ΔkW	=	Gross customer connected load kW savings for the measure.
ΔMMBtu	=	Gross customer annual MMBtu savings for the measure.
ΔT	=	Temperature difference between before and after turn down. = 15°F[1]
ηDHW	=	Recovery efficiency of electric water heater. = 0.98[2]

		Recovery efficiency of fossil fuel water heater = 0.76[3]
ΔkWh	=	Gross customer connected load kW savings for the measure.
1,000,000	=	Conversion from BTU to MMBtu.
3412	=	Conversion from BTU to kWh.
8760	=	Number of hours in a year (savings are from reduced standby loss and are therefore assumed to be constant over the year).
A_{base}	=	Surface area of storage tank (square feet). = 23.18[4]
Hours	=	Number of hours in a year (savings are assumed to be constant over year). = 8760
U_{base}	=	Overall heat transfer coefficient (Btu/Hr-F-ft^2). = 1/20[5]

Baseline Efficiencies

The baseline condition is a hot water tank with a thermostat setting that is higher than 125°F, typically 130°F or higher.

High Efficiency

High efficiency is a hot water tank with the thermostat set at 120°F or less.

Operating Hours

8766, savings are from reduced standby loss and are therefore assumed to be constant over the year.

Load Shapes

25a Flat (8760 hours)

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
25	Flat (8760 hours)	Active	31.7 %	34.9 %	15.9 %	17.5 %	100.0 %	100.0 %

Net Savings Factors

Measures

HWETEMPS	Hot water temperature setback

Tracks [Base Track]

6036RETR [is base track]	Res Retrofit

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Res Retrofit	6036RETR	HWETEMPS	0.90	1.00

Persistence

The persistence factor is assumed to be one.

Lifetimes

2 years.

Analysis period is the same as the lifetime.

Measure Cost

$5 for contractor time.

O&M Cost Adjustments

There are no operation and maintenance cost adjustments for this measure

Fossil Fuel Description

Footnotes

[1] Assumes 135°F tank turned down to 120°F.

[2] NREL, National Residential Efficiency Measures Database, http://www.nrel.gov/ap/retrofits/measures.cfm?gId=6&ctId=40

[3] NREL, National Residential Efficiency Measures Database, http://www.nrel.gov/ap/retrofits/measures.cfm?gId=6&ctId=40

[4] Area includes tank sides and top, for a 40 gallon tank. Assumptions from Pennsylvania Public Utility Commission Technical Reference Manual (PA TRM). Area values were calculated from average dimensions of several commercially available units, with radius values measured to the center of the insulation. Area includes tank sides and top to account for typical wrap coverage.

[5] Assumes an existing well insulated tank, or that tank wrap is added at that same time as the turn-down. Assumptions from Pennsylvania Public Utility Commission Technical Reference Manual (PA TRM).

Low Flow Showerhead

Measure Number: VII-A-4 f
Portfolio: EVT TRM Portfolio 2018-03
Status: Active
Effective Date: 2018/1/1
End Date: [None]
Program: Existing Homes
End Use: Hot Water

Update Summary

Measure has been updated to add assumptions for free products given to customers who request them.

Referenced Documents

- DEER2014-EUL-table-update_2014-02-05.xlsx
- Cadmus_Ameren Missouri EP Impact & Process Evaluation_May 2016
- Cadmus_Showerhead and Faucet Aerator Meter Study_June 2013
- Navigant_energySMART Energy Savings Kits_Apr 2016
- U.S. Census Bureau_ACS Table DP04 Vermont_2015
- U.S. DOE_Building America Standard DHW Schedules_May 2014
- VT Res Baseline SFNC Onsite report - DRAFT 051217
- EPA_WaterSense Labeled Products_Dec 2017
- EVT_RNC DHW Eff Calculation_Jan 2018
- EVT_Low Flow Showerhead_Analysis_Feb 2018

Description

This measure characterizes the installation of a low-flow showerhead in a single family home or a multifamily building. The qualifying efficient flow rate for direct install and free giveaway programs is 1.5 gallons per minute (gpm). For the RNC program, the qualifying flow rate is a WaterSense-labeled showerhead. The measure applies to RNC, retrofit direct install implementation, or free giveaways to customers who request products.

Algorithms

Electric Demand Savings

ΔkW = ΔkWh / HOURS

Symbol Table

Electric Energy Savings

ΔkWh = ((GPM$_{base}$ - GPM$_{low}$) × Tshower × # people × # showers × usedays/year / SH/home × 8.3 × 1.0 × (TEMP$_{sh}$ - TEMP$_{in}$) / η Electric_DHW / 3,412) × ISR × %Electric_DHW

Symbol Table

Fossil Fuel Savings

ΔMMBtu = ((GPM$_{base}$ - GPM$_{low}$) × Tshower × # people × # showers × usedays/year / SH/home × 8.3 × 1.0 × (TEMP$_{sh}$ - TEMP$_{in}$) / ηFuel_DHW / 1,000,000) × ISR × %Fuel_DHW

Symbol Table

Water Savings

ΔCCF = ((GPM$_{base}$ - GPM$_{low}$) × Tshower × # people × # showers × usedays/year / SH/home / 748) × ISR

Where:

people = Average number of people per household
= 2.33[2]

showers = Showers per person per day
= 0.6[3]

%Electric_DHW = For direct install or RNC, 100% if electric DHW system, 0% if non-electric DHW system
= 25%[4] for free giveaways

%Fuel_DHW = Proportion of water heating supplied by fuel oil, natural gas, or propane
= For direct install or RNC, 100% if fuel DHW system, 0% if non-fuel DHW system
= For free products assume:[4]

Fuel Oil	Natural Gas	Propane
20%	26%	27%

ΔCCF = Gross customer annual water savings for the measure
See Reference Tables section for deemed savings values.

ΔkW = Gross customer connected load kW savings for the measure
See Reference Tables section for deemed savings values.

ΔkWh = Gross customer annual kWh savings for the measure
See Reference Tables section for deemed savings values.

ΔMMBtu = Gross customer annual MMBtu savings for the measure
See Reference Tables section for deemed savings values.

ηElectric_DHW = Recovery efficiency of electric water heater
= 0.98[5]

ηFuel_DHW = Recovery efficiency of fuel water heater
= 0.78[16] for direct install or free giveaways
= 0.89[17] for RNC

1,000,000 = Conversion factor from Btu to MMBtu

1.0 = Specific heat of water (Btu/lb-°F) (constant)

3,412 = Conversion factor from Btu to kWh

748 = Constant to convert from gallons to CCF

8.3 = Constant to convert gallons to lbs

GPM_{base} = Flow rate (gpm) of baseline showerhead
= 2.5 gpm for direct install or free giveaways[6]
= 2.4 gpm for RNC[7]

GPM_{low} = Flow rate (gpm) of low flow showerhead
= 1.5 gpm for direct install or free giveaways[8]
= 1.9 gpm for RNC[9]

HOURS = Annual full load hours
= 3,427.1 hours[1]

ISR = In service rate, or the percentage of units rebated that are actually installed
= 100% for direct install or RNC
= 56%[10] for free products

SH/home = Average number of showerheads per household
= 1.3 for existing homes or multifamily buildings[11]
= 2.1 for RNC[12]

$TEMP_{in}$ = Assumed temperature of water entering house
= 51.9 F[13]

$TEMP_{sh}$ = Assumed temperature of water coming from showerhead
= 101 F[14]

Tshower = Average shower length in minutes

= 7.8[15]

usedays/year = Days showerhead is used per year

= 365

Baseline Efficiencies

The baseline for direct install or free giveaways is a standard showerhead using 2.5 gpm. The baseline for RNC is a showerhead with a flow rate of 2.4 gpm.[7]

High Efficiency

The efficient condition for direct install or free giveaways is a showerhead with a flow rate of 1.5 gpm. The efficient condition for RNC is a showerhead with a flow rate of 1.9 gpm.[9]

Load Shapes

For DHW systems not on Utility Controlled DHW program (Default):
Loadshape #8, Residential DHW Conservation

For DHW systems on Utility Controlled DHW program:
Loadshape #54, Controlled DHW Conservation

Loadshapes #8 and #54 are based on Itron 8760 hourly load data.

8a Residential DHW conserve
54a Controlled DHW Conservation

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
8	Residential DHW conserve	Active	48.7 %	29.1 %	14.3 %	7.9 %	40.1 %	20.3 %
54	Controlled DHW Conservation	Active	48.7 %	29.1 %	14.3 %	7.9 %	20.5 %	12.1 %

Net Savings Factors

Measures

HWESHOWR	Low flow showerhead

Tracks [Base Track]

6018LINC [is base track]	LIMF NC
6019MFNC [is base track]	MF Mkt NC
6034LISF [is base track]	LISF Retrofit
6036RETR [is base track]	Res Retrofit
6038VESH [is base track]	RNC VESH
6017PRES [is base track]	6017PRES
6017CUST [is base track]	6017CUST
6020PRES [is base track]	6020PRES

Persistence

The persistence factor is assumed to be one.

Lifetimes

The measure life is assumed to be 10 years.[18]

Analysis period is the same as the lifetime.

Measure Cost

The measure cost for direct install is the actual program cost (material and labor) of installing the new showerhead: $15.

The measure cost for free giveaways is the actual program cost of a new showerhead: $4.75.

The incremental measure cost for RNC is $7.[19]

O&M Cost Adjustments

There are no operation and maintenance cost adjustments for this measure.

Reference Tables

Savings are presented below, depending on program type.[20]

Program Type	ΔkW	ΔkWh	ΔMMBtu (fuel oil)	ΔMMBtu (natural gas)	ΔMMBtu (propane)	ΔCCF
Direct Install	0.10888	373.1	1.600	1.600	1.600	4.09
RNC	0.03370	115.5	0.434	0.434	0.434	1.27
Free Products	0.01524	52.2	0.179	0.233	0.242	2.29

Footnotes

[1] Full load hours from Loadshape #8a (Residential DHW Conserve) and #54a (Controlled DHW Conservation).

[2] Weighted average household size of owner-occupied versus renter-occupied housing units ((71% * 2.42) + (29% * 2.12)) based on 2011-2015 American Community Survey 5-Year Estimates for Vermont. See reference file U.S. Census Bureau_ACS Table DP04 VT_2015.pdf.

[3] Cadmus and Opinion Dynamics, for the Michigan Evaluation Working Group, "Showerhead and Faucet Aerator Meter Study Memorandum," June 2013, page 11, Table 8.

[4] DHW fuel percentages for free products based on data received by Efficiency Vermont on 08/21/2017 from the upcoming NMR Vermont Residential Market Assessment.

[5] Review of AHRI database shows that electric water heaters have a recovery efficiency of 98%.

Note that during November 2017 TAG, EVT and DPS agreed that assumptions for HPWH will be added during the next TRM reliability update cycle in 2020.

[6] The Energy Policy Act of 1992 (EPAct) established the maximum flow rate for showerheads at 2.5 gallons per minute (gpm), which is the minimum qualifying flow rate for Efficiency Vermont direct install programs. Baseline flow rate is verified on site by reviewing the equipment label and measuring the flow rate. However, baseline flow rates are not recorded.

[7] Average showerhead flow rate in new single-family homes from NMR Group, "Vermont Residential New Construction Baseline Study Analysis of On-Site Audits (Draft Report)," May 12, 2017, page 11, Table 6.

[8] Flow rate of showerhead provided by program.

[9] Efficient showerhead flow rate for RNC is the average flow rate of products on the WaterSense Labeled Products list as of December 4, 2017. See file EPA_WaterSense Labeled Products_Dec 2017.xlsx.

[10] Average of showerhead in service rate for kits including one showerhead (65%) from Navigant, "energySMART Energy Savings Kits, GPY 4 Evaluation Report (FINAL)," April 29, 2016, p. 20, and kits showerhead in service rate for single family homes (47%) from Cadmus, "Ameren Missouri Efficient Products Impact and Process Evaluation: PY 2015," May 13, 2016, p. 23.

[11] Average of values for single family and multifamily households from Cadmus and Opinion Dynamics, for the Michigan Evaluation Working Group, "Showerhead and Faucet Aerator Meter Study Memorandum," June 2013, page 12, Table 9.

[12] Average number of low-flow showerheads from NMR Group, "Vermont Residential New Construction Baseline Study Analysis of On-Site Audits (Draft Report)," May 12, 2017, page 12. Low flow is defined in the RNC report as 2.5 GPM, which is the maximum flow rate established by the Energy Policy Act of 1992 (EPAct). Since the saturation rate of low-flow showerheads is 98% for new homes in EVT territory (Table 8, page 13), EVT assumes 2.1 showerheads/home is a reasonable assumption for RNC.

[13] Average value for Burlington, Montpelier. Rutland, and Springfield, VT from U.S. DOE Standard Building America DHW Schedules, May 2014.

[14] Cadmus and Opinion Dynamics, for the Michigan Evaluation Working Group, "Showerhead and Faucet Aerator Meter Study Memorandum," June 2013, page 11, Table 7.

[15] Cadmus and Opinion Dynamics, for the Michigan Evaluation Working Group, "Showerhead and Faucet Aerator Meter Study Memorandum," June 2013, page 10, Table 6.

[16] Based on a review of fuel DHW systems available in AHRI database.

[17] The fuel DHW system recovery efficiency for RNC is a weighted average based on the distribution of DHW system types in new homes from NMR Group, "Vermont Residential New Construction Baseline Study Analysis of On-Site Audits (Draft Report)," May 12, 2017. Energy factors from the Vermont RNC report were converted to recovery efficiencies using information from the AHRI database. See file EVT_RNC DHW Eff Calculation_Jan 2018.xlsx for details.

[18] Measure lifetime from California DEER. See file DEER2014-EUL-table-update_2014-02-05.xlsx.

[19] Based on a review of available products on HomeDepot.com during January 2018.

[20] See file EVT_Low Flow Showerhead_Analysis_Feb 2018.xlsx for calculation details.

Low Flow Faucet Aerator

Measure Number: **VII-A-5 d**
Portfolio: EVT TRM Portfolio 2017-07
Status: Active
Effective Date: 2017/1/1
End Date: [None]
Program: Existing Homes
End Use: Hot Water

Update Summary

The following changes have been made:

- Measure has been updated according to the 3-year reliability update timeline.
- Separate Low-Flow Faucet Aerator measures under the Existing Homes, Low Income Single Family, and Multifamily programs have been combined.
- Assumptions have been added for free products through Vermont Foodbanks.

Note that during November 2017 TAG, EVT and DPS agreed that assumptions for HPWH will be added during the next TRM reliability update cycle in 2020.

Referenced Documents

- DEER2014-EUL-table-update_2014-02-05.xlsx
- Cadmus_Ameren Missouri EP Impact & Process Evaluation_May 2016
- Cadmus_Showerhead and Faucet Aerator Meter Study_June 2013
- Navigant_energySMART Energy Savings Kits_Apr 2016
- Navigant_Measures and Assumptions for Demand Side Management Planning_Apr 2009
- NMR_Survey Analysis of Owners in Existing Homes in Vermont_Dec 2016
- Schultdt_Energy Related Water Fixture Measurements_2008
- US Census Bureau_ACS Table DP04 Vermont_2015
- US DOE_Building American Standard DHW Scedules_May 2014
- EVT_Low Flow Faucet Aerators_Analysis_June 2017_v5

Description

This measure relates to the installation of a low flow faucet aerator in a single family home or multifamily building. Low flow faucet aerators reduce the consumption of hot water and as a result, the energy required to heat it. The measure applies to retrofit direct install implementation or free giveaways through Vermont Foodbanks.

Algorithms

Electric Demand Savings

$$\Delta kW = \Delta kWh / HOURS$$

Symbol Table

Electric Energy Savings

$$\Delta kWh = ((((GPM_{base} \times Throttle_{base}) - (GPM_{low} \times Throttle_{low})) \times Tperson/day \times \#\ people \times usedays/year \times DR) \times 8.3 \times 1.0 \times (TEMP_{faucet} - TEMP_{in}) / \eta Electric\_DHW / 3{,}412) \times ISR \times \%Electric\_DHW$$

Symbol Table

Water Savings

$$\Delta CCF = ((GPM_{base} \times Throttle_{base}) - (GPM_{low} \times Throttle_{low})) \times Tperson/day \times \#\ people \times usedays/year \times DR / 748 \times ISR$$

Symbol Table

Fossil Fuel Savings

$$\Delta MMBtu = ((((GPM_{base} \times Throttle_{base}) - (GPM_{low} \times Throttle_{low})) \times Tperson/day \times \#\ people \times usedays/year \times DR \times 8.3 \times 1.0 \times (TEMP_{faucet} - TEMP_{in}) / 1{,}000{,}000 / \eta Fuel\_DHW) \times ISR \times \%Fuel\_DHW$$

Where:

\# people = Average number of people per household
= 2.33[2]

%Electric_DHW = Proportion of water heating supplied by electricity

= For Direct Install, 100% if electric DHW system, 0% if non-electric DHW system

= 25%[3] for free products at Vermont Foodbanks

%Fuel_DHW = Proportion of water heating supplied by fuel oil, natural gas, or propane

= For Direct Install where DHW fuel type is known, 100% if fuel DHW system, 0% if non-fuel DHW system

= For Direct Install where DHW fuel type is unknown or for free products at Vermont Foodbanks, assume:[3]

Fuel Oil	Natural Gas	Propane
20%	26%	27%

ΔCCF = Customer water savings in hundreds of cubic feet for the measure

See Reference Tables section for deemed savings values.

ΔkW = Gross customer connected load kW savings for the measure

See Reference Tables section for deemed savings values.

ΔkWh = Gross customer annual kWh savings for the measure

See Reference Tables section for deemed savings values.

ΔMMBtu = Gross customer annual MMBtu savings for the measure

See Reference Tables section for deemed savings values.

ηElectric_DHW = Recovery efficiency of electric water heater

= 0.98[4]

ηFuel_DHW = Recovery efficiency of fuel water heater

= 0.78[12]

1,000,000 = Conversion factor from Btu to MMBtu

1.0 = Specific heat of water (Btu/lb-°F) (constant)

3,412 = Conversion factor from Btu to kWh

748 = Constant to convert from gallons to CCF

8.3 = Constant to convert gallons to lbs

DR = Percentage of water flowing down drain

= 63%[5]

GPM_{base} = Flow rate (gpm) of baseline faucet

= 2.2[6]

GPM_{low} = Flow rate (gpm) of low flow faucet

= 1.0 or 1.5 gpm for Direct Install

= 1.5 gpm for free products

HOURS = Annual full load hours

= 3,427.1 hours[1]

ISR = In service rate, or the percentage of units rebated that are actually installed

= 100% for Direct Install and 58%[7] for free products

$TEMP_{faucet}$ = Assumed temperature of water used by faucet

= 88 F[8]

$TEMP_{in}$ = Assumed temperature of water entering house

= 51.9 F[9]

$Throttle_{base}$ = Ratio of user setting to full-throttle flow rate for baseline faucet

= 0.83[10]

$Throttle_{low}$ = Ratio of user setting to full-throttle flow rate for low flow faucet

= 0.95[10]

Tperson/day = Average daily length of use per person, per faucet (min/person/faucet)

= 1.6[11]

usedays/year = Days faucet used per year

= 365 days

Baseline Efficiencies

The baseline is assumed to be a standard faucet aerator with a flow rate of 2.2 gpm. Savings assumptions include a 0.83 throttling factor for baseline faucets to account for the fact that faucets are not always operated at full flow, reducing the flow rate to 1.83 gpm.

High Efficiency

The efficient condition is a faucet aerator with a flow rate of either 1.0 gpm or 1.5 gpm for direct install programs and 1.5 gpm for free giveaways. Savings assumptions include a 0.95 throttling factor for new faucets to account for the fact that faucets are not always operated at full flow, reducing the flow rate to 0.95 gpm for 1.0 gpm aerators and 1.4 gpm for 1.5 gpm aerators.

Load Shapes

For DHW systems not on Utility Controlled DHW program (Default):
Loadshape #8, Residential DHW Conservation

For DHW systems on Utility Controlled DHW program:
Loadshape #54, Controlled DHW Conservation

Loadshapes #8 and #54 are based on Itron 8760 hourly load data.

8a Residential DHW conserve
54a Controlled DHW Conservation

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
8	Residential DHW conserve	Active	48.7 %	29.1 %	14.3 %	7.9 %	40.1 %	20.3 %
54	Controlled DHW Conservation	Active	48.7 %	29.1 %	14.3 %	7.9 %	20.5 %	12.1 %

Net Savings Factors

Measures

HWEFAUCT	Faucet aerator/flow restrictor

Tracks [Base Track]

6032EPEP [is base track]	Efficient Products - Residential
6034LISF [is base track]	LISF Retrofit
6036RETR [is base track]	Res Retrofit
6032LIEP [6032EPEP]	Efficient Products - Low Income

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Efficient Products - Residential	6032EPEP	HWEFAUCT	1.00	1.00
LISF Retrofit	6034LISF	HWEFAUCT	1.00	1.00
Res Retrofit	6036RETR	HWEFAUCT	0.90	1.00

Persistence

The persistence factor is assumed to be one.

Lifetimes

The measure life is assumed to be 10 years.[13]

Analysis period is the same as the lifetime.

Measure Cost

For Direct Install, the measure cost is the actual material and labor cost of installing the new aerator. If actual costs are unknown, assume a full install cost of $8 (market research average of $3 for faucet aerator and assess and install cost of $5.00, based on 20 minutes of labor at $15/hour).

For new products at Vermont Foodbanks, assume a measure cost of $3 (market research average).

O&M Cost Adjustments

There are no operation and maintenance cost adjustments for this measure.

Reference Tables

Savings are presented below, depending on program type.[14]

Program Type	ΔkW	ΔkWh	ΔMMBtu (fuel oil)	ΔMMBtu (natural gas)	ΔMMBtu (propane)	ΔCCF
Direct Install (electric DHW, 1.0 GPM)	0.01964	67.3				1.00
Direct Install (oil DHW, 1.0 GPM)			0.288			1.00
Direct Install (natural gas DHW, 1.0 GPM)				0.288		1.00
Direct Install (propane DHW, 1.0 GPM)					0.288	1.00
Direct Install (DHW fuel type unknown, 1.0 GPM)	0.00569	19.5	0.089	0.049	0.089	1.00
Direct Install (electric DHW, 1.5 GPM)	0.00899	30.8				0.46
Direct Install (oil DHW, 1.5 GPM)			0.132			0.46
Direct Install (natural gas DHW, 1.5 GPM)				0.132		0.46
Direct Install (propane DHW, 1.5 GPM)					0.132	0.46
Direct Install (DHW fuel type unknown, 1.5 GPM)	0.00261	8.9	0.041	0.022	0.041	0.46
Free Products at Vermont Foodbanks	0.00130	4.5	0.015	0.020	0.021	0.27

Footnotes

[1] Full load hours from Loadshape #8a (Residential DHW Conserve) and #54a (Controlled DHW Conservation).

[2] Weighted average household size of owner-occupied versus renter-occupied housing units ((71% * 2.42) + (29% * 2.12)) based on 2011-2015 American Community Survey 5-Year Estimates for Vermont. See reference file U.S. Census Bureau_ACS Table DP04 VT_2015.pdf.

[3] Percentage of DHW fuels for free products giveaways based on data received by Efficiency Vermont on 08/21/2017 from the upcoming NMR Vermont Residential Market Assessment.

[4] Review of AHRI database shows that electric water heaters have a recovery efficiency of 98%.

Note that during November 2017 TAG, EVT and DPS agreed that assumptions for HPWH will be added during the next TRM reliability update cycle in 2020.

[5] Because faucet usages are at times dictated by volume (for example, filling a sink to wash dishes), only usage that would allow water to go straight down the drain will provide savings. DR values are from Navigant Consulting, Inc. for the Ontario Energy Board, "Measures and Assumptions for Demand Side Management Planning, Appendix C: Substantiation Sheets," April 16, 2009, pages C-57 and C-61. DR values weighted by typical number of kitchen faucets (1 faucet) and bath faucets (2 faucets) in a household: (1/3 * 0.50) + (2/3* 0.70) = 0.63.

[6] Federal standard for faucets, 10 CFR 430.32(o)

[7] Average of kits bathroom aerator in service rate (63%) from Navigant, "energySMART Energy Savings Kits, GPY 4 Evaluation Report (FINAL)," April 29, 2016, p. 20, and kits bathroom aerator in service rate for single family homes (52%) from Cadmus, "Ameren Missouri Efficient Products Impact and Process Evaluation: PY 2015," May 13, 2016, p. 23.

[8] Cadmus and Opinion Dynamics, for the Michigan Evaluation Working Group, "Showerhead and Faucet Aerator Meter Study Memorandum," June

2013, Table 7, page 11. $TEMP_{faucet}$ values weighted by typical number of kitchen faucets (1 faucet) and bath faucets (2 faucets) in a household: (1/3 * 93) + (2/3* 86) = 88.

[9] Average value for Burlington, Montpelier. Rutland, and Springfield, VT from U.S. DOE Standard Building America DHW Schedules, May 2014.

[10] Schultdt, Marc, and Debra Tachibana, "Energy Related Water Fixture Measurements: Securing the Baseline for Northwest Single Family Homes. 2008 ACEEE Summer Study on Energy Efficiency in Buildings," 2008, page 1-265.

[11] Cadmus and Opinion Dynamics, for the Michigan Evaluation Working Group, "Showerhead and Faucet Aerator Meter Study Memorandum," June 2013, Table 6, page 10.

[12] Based on a review of fuel DHW systems available in AHRI database.

[13] Measure lifetime from California DEER. See file DEER2014-EUL-table-update_2014-02-05.xlsx.

[14] See file EVT_Low Flow Faucet Aerators_Analysis_June 2017_v5.xlsx for calculation details.

Central Wood Pellet Boilers and Furnaces

Measure Number:	VII-C-10 c
Portfolio:	EVT TRM Portfolio 2018-02
Status:	Active
Effective Date:	2018/1/1
End Date:	[None]
Program:	Existing Homes
End Use:	HVAC

Update Summary

Several assumptions have been updated in response to 2017 TAG discussions, revisions made to other measures during FY 2017, and updated cost information:

- %Elec and %Fuel for both residential and commercial buildings, to reflect updated Vermont market assessment reports
- nBase values for commercial buildings, to reflect the updated Vermont market assessment report for existing buildings and to match the updated Efficient Space Heating Systems measure for new construction
- Residential FLH values, to match a revised analysis based on VGS data
- The Commercial FLH value, calculated based on NY TRM FLH values and Vermont building data provided by Cadmus
- O&M and measure cost values, to reflect the 2016 version of the EIA "Updated Buildings Sector and Appliance and Equipment Costs and Efficiencies" report and to average costs for 2013 and 2020, and to reflect the percentage of fuel and heating system types from the updated Vermont market assessment reports
- The pellet wood penalty, to reflect that in 2018 and forward, in TEPF-funded programs, EVT is not counting the increased wood fuel use associated with biomass fuel switches from fossil fuels.

Referenced Documents

- US DOE, "Technical Support Document for Commercial Packaged Boilers", 2016.
- NEEP_EMV_EmergingTechResearch_Report_Final
- rerc-advanced-wood-pellet-system-eligible-equipment-inventory-vfy2016
- VT SF Existing Homes Onsite Report_final 021513
- VGS Usage Regression Work_04182017
- 2016 Vermont Business Sector Market Characterization and Assessment Study
- NMR_Survey Analysis of Owners in Existing Homes in Vermont_Dec 2016
- EVT_Commercial EFLH_Analysis_July 2017
- EIA_Updated Buildings Sector Appliance and Equipment Costs and Efficiencies_Nov 2016
- VT Res Baseline SFNC Onsite report - DRAFT 051217
- EVT_Central Wood Pellet Boilers and Furnaces_Analysis_Jan 2018

Description

This measure applies to the installation by an approved contractor of a new central wood pellet boiler or furnace rated less than or equal to 340,000 Btu/h (< 100 kW) in new or existing, residential or commercial buildings. For installations in existing buildings or homes, it is assumed that the existing space heating system will remain in place and that the new pellet system will satisfy 90%[1] of the building's heating load.

Pellet systems must be installed according to manufacturer's recommendations and meet the following minimum efficiency and emissions requirements:

- 85% peak efficiency based on higher heating value (HHV) at full-load conditions
- <0.08 lb/MMBtu of particulate matter less than 2.5 microns ($PM_{2.5}$)

Baseline Efficiencies

The baseline is a blend of LP, oil, wood, and electric heating systems, based on the percentage of each system installed as a primary heating source in existing Vermont buildings for retrofits or in new Vermont buildings for new construction (NC).

Efficient Equipment

The new equipment must be a new central wood pellet boiler or furnace installed according to manufacturer's recommendations and meeting minimum efficiency and emissions requirements. For existing buildings, the new pellet system is assumed to satisfy 90% of the building's heating load.

In 2018 and forward, in TEPF-funded programs, EVT will not count the increased wood fuel use associated with biomass fuel switches from fossil fuels. Therefore, beginning in 2018 this measure does not apply a pellet heating penalty, except when the baseline is wood.

Algorithms

Electric Demand Savings

ΔkW_{Res}	$= \Delta kWh_{Res}/FLH$
ΔkW_{Comm}	$= \Delta kWh_{Comm}/FLH$

Symbol Table

Electric Energy Savings

The electric energy savings from the installation of a new pellet heating system in place of an electric heating system are described below.

See table below[5] for deemed electric energy and demand savings based on customer, building type, and equipment capacity.

Customer	Building Type	Equipment Capacity (Btu/hr)	ΔkWh	ΔkW
Residential	Existing	25,000 – 80,000	139.8	0.17910
		>80,000 – 150,000	256.7	0.32889
		>150,000 – 340,000	526.1	0.67406
	NC	25,000 – 80,000	477.7	0.72924
		>80,000 – 150,000	877.1	1.33915
		>150,000 – 340,000	1797.7	2.74460
Commercial	Existing	25,000 – 80,000	311.2	0.29307
		>80,000 – 150,000	571.6	0.53818
		>150,000 – 340,000	1171.4	1.10301
	NC	25,000 – 80,000	2751.0	2.59035
		>80,000 – 150,000	5051.7	4.75682
		>150,000 – 340,000	10353.6	9.74914

ΔkWh_{Res} $= FLH \times (Capacity / 1,000,000) / \eta_{Base,\ Electric} \times 293.071 \times \%Pellet \times \%Elec$

ΔkWh_{Comm} $= FLH \times (Capacity / 1,000,000) / \eta_{Base,\ Electric} / OF \times 293.071 \times \%Pellet \times \%Elec$

Symbol Table

Fossil Fuel Savings

The fuel savings from the installation of a new pellet heating system in place of an LP, oil, or wood heating system, the fuel penallties from the installation of a new pellet heating system in place of a wood heating system, and net savings are described below . The fuel savings for each fuel type are summed to create a blended fuel savings value.

See table below[12] for deemed fuel savings, penalties, and net savings based on customer, building type, and equipment capacity.

Customer	Building Type	Equipment Capacity (Btu/hr)	Heating System	$\Delta MMBtu_{Save}$ (by fuel type)	$\Delta MMBtu_{Save}$ (total savings before applying pellet penalty)	$\Delta MMBtu_{Penalty}$	$\Delta MMBtu_{Net}$ (total savings after applying pellet penalty)
Residential	Existing	25,000 – 80,000	LP	7.665	47.550	8.285	39.265
			Oil	28.878			
			Wood	11.007			
		>80,000 – 150,000	LP	14.076	87.318	15.214	72.105
			Oil	53.030			
			Wood	20.212			
		>150,000 – 340,000	LP	28.848	178.960	31.181	147.779
			Oil	108.686			
			Wood	41.425			
Residential	NC	25,000 – 80,000	LP	20.807	34.467	9.850	24.617
			Oil	2.319			
			Wood	11.341			
		>80,000 – 150,000	LP	38.209	63.295	18.088	45.207
			Oil	4.259			
			Wood	20.827			
		>150,000 – 340,000	LP	78.310	129.723	37.071	92.651
			Oil	8.728			
			Wood	42.684			
		25,000 – 80,000	LP	33.945	54.078	0.000	54.078
			Oil	20.133			

			Wood	0.000			
Commercial	Existing	>80,000 – 150,000	LP	62.336	99.307	0.000	99.307
			Oil	36.971			
			Wood	0.000			
		>150,000 – 340,000	LP	127.757	203.530	0.000	203.530
			Oil	75.772			
			Wood	0.000			
Commercial	NC	25,000 - 80,000	LP	23.728	25.256	1.327	23.929
			Oil	0.000			
			Wood	1.528			
		>80,000 – 150,000	LP	43.573	46.379	2.437	43.941
			Oil	0.000			
			Wood	2.806			
		>150,000 – 340,000	LP	89.302	95.053	4.995	90.058
			Oil	0.000			
			Wood	5.751			

$\Delta MMBtu_{\text{Save, Res}} = \Delta MMBtu_{\text{Save, Res, LP}} + \Delta MMBtu_{\text{Save, Res, Oil}} + \Delta MMBtu_{\text{Save, Res, Wood}}$

$\Delta MMBtu_{\text{Save, Res, LP}} = FLH \times (Capacity / 1{,}000{,}000) / \eta_{\text{Base, LP}} \times \%Pellet \times \%Fuel_{LP}$

$\Delta MMBtu_{\text{Save, Res, Oil}} = FLH \times (Capacity / 1{,}000{,}000) / \eta_{\text{Base, Oil}} \times \%Pellet \times \%Fuel_{Oil}$

$\Delta MMBtu_{\text{Save, Res, Wood}} = FLH \times (Capacity / 1{,}000{,}000) / \eta_{\text{Base, Wood}} \times \%Pellet \times \%Fuel_{Wood}$

$\Delta MMBtu_{\text{Save, Comm}} = \Delta MMBtu_{\text{Save, Comm, LP}} + \Delta MMBtu_{\text{Save, Comm, Oil}} + \Delta MMBtu_{\text{Save, Comm, Wood}}$

$\Delta MMBtu_{\text{Save, Comm, LP}} = FLH \times (Capacity / 1{,}000{,}000) / OF / \eta_{\text{Base, LP}} \times \%Pellet \times \%Fuel_{LP}$

$\Delta MMBtu_{\text{Save, Comm, Oil}} = FLH \times (Capacity / 1{,}000{,}000) / OF / \eta_{\text{Base, Oil}} \times \%Pellet \times \%Fuel_{Oil}$

$\Delta MMBtu_{\text{Save, Comm, Wood}} = FLH \times (Capacity / 1{,}000{,}000) / OF / \eta_{\text{Base, Wood}} \times \%Pellet \times \%Fuel_{Wood}$

$\Delta MMBtu_{\text{Penalty, Res, Wood}} = FLH \times (Capacity / 1{,}000{,}000) / \eta_{\text{Pellet}} \times \%Pellet \times \%Fuel_{Wood}$

$\Delta MMBtu_{\text{Penalty, Comm, Wood}} = FLH \times (Capacity / 1{,}000{,}000) / OF / \eta_{\text{Pellet}} \times \%Pellet \times \%Fuel_{Wood}$

$\Delta MMBtu_{\text{Net, Res}} = \Delta MMBtu_{\text{Save, Res}} - \Delta MMBtu_{\text{Penalty, Res, Wood}}$

$\Delta MMBtu_{\text{Net, Comm}} = \Delta MMBtu_{\text{Save, Comm}} - \Delta MMBtu_{\text{Penalty, Comm, Wood}}$

Where:

%Elec = Percentage of buildings assumed to have baseboard electric heating systems; see table below

Building Type	Customer Type	%Elec
Existing	Residential[6]	1%
	Commercial[7]	2%
New Construction	Residential[8]	17%
	Commercial[9]	62%

$\%Fuel_{LP}$ = Percentage of buildings assumed to use LP heating systems; see table below for %Fuel for each building, customer, and fuel type.

Building Type	Customer Type	Fuel Type	%Fuel
Existing	Residential[6]	LP	17%
		Oil	63%
		Wood	19%
	Commercial[7]	LP	62%
		Oil	36%
		Wood	0%
New Construction	Residential[8]	LP	54%
		Oil	6%
		Wood	24%
	Commercial[9]	LP	36%
		Oil	0%
		Wood	2%

$\%Fuel_{Oil}$ = Percentage of buildings assumed to use oil heating systems; see table within $\%Fuel_{LP}$ definition.

$\%Fuel_{Wood}$ = Percentage of buildings assumed to use wood heating systems; see table within $\%Fuel_{LP}$ definition.

%Pellet = Percentage of annual heating load provided by pellet system

= 90%[1] for existing buildings and 100% for NC

ΔkW_{Comm} = Gross customer annual connected load kW savings for the measure (commercial customers)

ΔkW_{Res} = Gross customer annual connected load kW savings for the measure (residential customers)

ΔkWh_{Comm} = Gross customer annual kWh savings for the measure (commercial customers)

ΔkWh_{Res} = Gross customer annual kWh savings for the measure (residential customers)

$\Delta MMBtu_{Net, Comm}$ = Gross customer annual MMBtu fuel savings for the measure (commercial customers) after subtracting the pellet penalty

$\Delta MMBtu_{Net, Res}$ = Gross customer annual MMBtu fuel savings for the measure (residential customers) after subtracting the pellet penalty

$\Delta MMBtu_{Penalty, Comm, Wood}$ = Gross customer annual MMBtu fuel penalty for the measure (commercial customers) for pellet systems displacing wood space heating

$\Delta MMBtu_{Penalty, Res, Wood}$ = Gross customer annual MMBtu fuel penalty for the measure (residential customers) for pellet systems displacing wood space heating

$\Delta MMBtu_{Save, Comm, LP}$ = Gross customer annual MMBtu fuel savings for the measure (commercial customers, LP baseline)

$\Delta MMBtu_{Save, Comm, Oil}$ = Gross customer annual MMBtu fuel savings for the measure (commercial customers, oil baseline)

$\Delta MMBtu_{Save, Comm, Wood}$ = Gross customer annual MMBtu fuel savings for the measure (commercial customers, wood baseline)

$\Delta MMBtu_{Save, Comm}$ = Gross customer annual MMBtu fuel savings for the measure (commercial customers, total savings) before applying the pellet penalty

$\Delta MMBtu_{Save, Res, LP}$ = Gross customer annual MMBtu fuel savings for the measure (residential customers, LP baseline)

$\Delta MMBtu_{Save, Res, Oil}$ = Gross customer annual MMBtu fuel savings for the measure (residential customers, oil baseline)

$\Delta MMBtu_{Save, Res, Wood}$ = Gross customer annual MMBtu fuel savings for the measure (residential customers, wood baseline)

$\Delta MMBtu_{Save, Res}$ = Gross customer annual MMBtu fuel savings for the measure (residential customers, total savings) before applying the pellet penalty

η_{Pellet} = Efficiency of new pellet heating system, based on HHV

= 86%[13]

$\eta_{Base, LP}$ = Efficiency of baseline LP heating system; see table below for ηBase values based on building, customer, and fuel type.

Building Type	Customer Type	Fuel Type	η_{Base}
Existing	Residential[14]	Electric	100%
		LP	87.1%

		Oil	84.2%
		Wood	65%
	Commercial[15]	Electric	100%
		LP	88%
		Oil	84%
		Wood	65%
New Construction	Residential[16]	Electric	3.7 COP
		LP	93.8%
		Oil	86.3%
		Wood	75%
	Commercial[17]	Electric	3.5 COP
		LP	81%
		Oil	83%
		Wood	75%

$\eta_{Base, Electric}$ = Efficiency of baseline electric heating system; see table within $\eta_{Base, LP}$ definition.

$\eta_{Base, Oil}$ = Efficiency of baseline oil heating system; see table within $\eta_{Base, LP}$ definition.

$\eta_{Base, Wood}$ = Efficiency of baseline wood heating system; see table within $\eta_{Base, LP}$ definition.

1,000,000 = Factor to convert Btu/hr to MMBtu/hr

293.071 = Factor to convert MMBtu to kWh

Capacity = Output capacity (Btu/hr) of new pellet boiler or furnace; see table below for default capacity based on capacity bin[10]

Capacity Bin	Default Capacity (Btu/hr)
25,000 – 80,000	55,000
>80,000 – 150,000	101,000
>150,000 – 340,000	207,000

FLH = Estimated average full load heating hours; see table below

Customer Type	Building Type	FLH
Residential	Existing[2]	780
	New Construction[3]	655
Commercial[4]	Existing and New Construction	1,062

OF = Oversize factor: ratio of heating unit size to actual heating load

= 1.1[11]

Load Shapes

17a Commercial Space heat
5b Residential Space heat

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
17	Commercial Space heat	Active	38.7 %	61.2 %	0.0 %	0.1 %	57.0 %	0.3 %
5	Residential Space heat	Active	42.9 %	57.1 %	0.0 %	0.0 %	25.0 %	0.0 %

Net Savings Factors

Measures

SHFBBIOM	Biomass Fuel Switch

Tracks [Base Track]

6012CNIR [is base track]	C&I Retro

6013PRES [is base track]	Pres Equip Rpl
6036RETR [is base track]	Res Retrofit
6014PRES [is base track]	6014PRES

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
C&I Retro	6012CNIR	SHFBBIOM	0.79	1.00
Pres Equip Rpl	6013PRES	SHFBBIOM	0.80	1.00
Res Retrofit	6036RETR	SHFBBIOM	0.80	1.00
6014PRES	6014PRES	SHFBBIOM	0.80	1.05

Lifetimes

The expected measure life is assumed to be 20 years.[18]

Measure Cost

For existing buildings, the measure cost is the cost of installation (labor and equipment) for a pellet boiler or furnace: $20,000.[19]

For new construction, the measure cost is the incremental full installation cost difference (labor and equipment) between a new LP, oil, wood, or electric heating system and a new, qualifying pellet heating system. See table below for costs related to new construction.

Customer	Measure Cost
Residential[20]	$13,322
Commercial[21]	$11,764

O&M Cost Adjustments

For existing buildings, the annual O&M cost is the incremental O&M cost difference between LP, oil, wood, or electric heating systems and a blended assumption of 90% pellet heat and 10% LP, oil, wood, or electric resistance heat.

For new construction, the annual O&M cost is the incremental O&M cost difference between LP, oil, wood, or electric heating systems and 100% pellet heat.

Annual O&M costs for pellet boilers and furnaces are assumed to be $250.[22] See table below for O&M cost adjustments, which represent a penalty (increase in costs).

Customer	Building Type	O&M Cost Adjustment
Residential	Existing[23]	$122
	NC[24]	$141
Commercial	Existing[25]	$159
	NC[26]	$156

Footnotes

[1] Energy & Research Solutions, “Emerging Technologies Research Report,” (report prepared for the Regional Evaluation, Measurement, and Verification Forum, February 13, 2013): page 9-22.

[2] Residential FLH for existing homes is a weighted average of FLH for boilers and furnaces in existing homes. Boiler and furnace weightings are from NMR Group, "VT SF Existing Homes Onsite Report," 2013, Table 5-4. FLH values were estimated by following a methodology outlined in the Uniform Methods Project using natural gas billing data provided by Vermont Gas Systems (VGS) for homes that participated in Efficiency Vermont’s Residential New Construction (RNC) program. Since capacity has not been collected through the Home Performance with ENERGY STAR program it was not possible to perform the analysis with a more appropriate data set for this program. For Existing Homes, the RNC data was limited to only those homes with annual gas consumption greater than 25kBtu/sq ft in an attempt to remove the high performance/ low load homes in RNC. See ‘VGS Usage Regression Work_04182017.xls’ for analysis.

[3] Residential FLH for new construction is a weighted average of FLH for boilers and furnaces in new homes. Boiler and furnace weightings from page 47, Table 47, NMR Group, "Vermont Residential New Construction Baseline Study Analysis of On-Site Audits (Draft Report)," Prepared by NMR Group for Vermont DPS, May 12, 2017. Combined appliances, wood stoves and furnaces, pellet stoves, natural gas units, and heat pumps removed. Values for Efficiency Vermont used. FLH values were estimated by following a methodology outlined in the Uniform Methods Project using natural gas billing data provided by Vermont Gas Systems (VGS) for homes that participated in Efficiency Vermont’s Residential New Construction (RNC) program. Since capacity has not been collected through the Home Performance with ENERGY STAR program it was not possible to perform the analysis with a more appropriate data set for this program. See ‘VGS Usage Regression Work_04182017.xls’ for analysis. FLH values were estimated by following a methodology outlined in the Uniform Methods Project using natural gas billing data provided by Vermont Gas Systems (VGS) for homes that participated in Efficiency Vermont’s Residential New Construction (RNC) program. Since capacity has not been collected through the Home Performance with ENERGY STAR program it was not possible to perform the analysis with a more appropriate data set for this program. See ‘VGS Usage Regression Work_04182017.xls’ for analysis.

[4] Commercial FLH is a weighted average of commercial FLH values from New York Joint Utiliites,"New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs (Version 4)," April 29, 2016 and Vermont building data provided by Cadmus. See file EVT_Commercial

EFLH_Analysis_July 2017.xlsx for calculation details.

[5] For electric energy and demand calculations, see file EVT_Central Wood Pellet Boilers and Furnaces_Analysis_Jan 2018.xlsx.

[6] Percentage of heating fuel types in existing Vermont homes from NMR Group, "Survey Analysis of Owners of Existing Homes in Vermont (Draft)," December 5, 2016: page 29, Table 38 (Efficiency Vermont data). Natural gas, coal, and solar were excluded. The report states that "all nine respondents who use electricity as their primary heating fuel reported that they have electric resistance baseboard rather than an electric heat pump." Percentage of cordwood (versus pellets) estimated as 15%. See file EVT_Central Wood Pellet Boilers and Furnaces_Analysis_Jan 2018.xlsx.

[7] Percentage of heating system fuel types in existing Vermont commercial buildings based on data from Cadmus, "2016 Vermont Business Sector Market Characterization and Assessment Study," April 30, 2017: page 63, Figure 46 (Efficiency Vermont data). Natural gas, "unknown," and "other" heating systems were excluded. Percentage of electric resistance heating systems estimated at 1% based on Figure 47. See file EVT_Central Wood Pellet Boilers and Furnaces_Analysis_Jan 2018.xlsx.

[8] Percentage of heating system fuel types in new residential buildings in Vermont based on data from NMR Group, "Vermont Residential New Construction Baseline Study Analysis of On-Site Audits (Draft Report)," May 12, 2017: page 45, Table 46 (Efficiency Vermont data). Natural gas and pellets excluded. See file EVT_Central Wood Pellet Boilers and Furnaces_Analysis_Jan 2018.xlsx.

[9] Percentage of heating system fuel types in new Vermont commercial buildings based on data from Cadmus, "2016 Vermont Business Sector Market Characterization and Assessment Study," April 30, 2017: page 177, Figure 128 (Efficiency Vermont data). Natural gas and "unknown," heating systems were excluded. The report states that "other" is made up primarily of wood-fired boilers, but according to the raw data provided by Cadmus to Efficiency Vermont, 2 of the 4 systems in this category are pellet systems. These 2 systems were removed from the analysis. See file EVT_Central Wood Pellet Boilers and Furnaces_Analysis_Jan 2018.xlsx.

[10] Based on pellet system models available from Renewable Energy Resource Center, "Small Scale Renewable Energy Incentive Program (SSREIP) Advanced Wood Pellet Heating System Eligible Equipment Inventory," June 6, 2016. See EVT_Central Wood Pellet Boilers and Furnaces_Analysis_Jan 2018.xlsx for capacity bin calculations.

[11] Oversizing factor determined from US Department of Energy, "Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Commercial Packaged Boilers," March 4, 2016: pages 7-3 and 7-10. Oversizing Factor = 1.1; 10% larger unit than required "based on typical sizing practices."

[12] For fossil fuel savings calculations, see file EVT_Central Wood Pellet Boilers and Furnaces_Analysis_Jan 2018.xlsx.

[13] Weighted average efficiency of qualified models available on Renewable Energy Resource Center, "Small Scale Renewable Energy Incentive Program (SSREIP) Advanced Wood Pellet Heating System Eligible Equipment Inventory," June 6, 2016.

[14] Efficiencies for existing residential LP and oil heating systems are a weighted average based on the percentage of boilers and furnaces used as single major heating system in existing Vermont homes, from NMR Group, "Vermont Single-Family Existing Homes Onsite Report," February 15, 2013: pages 58-61, Tables 5-4, 5-8 and 5-9. See file EVT_Central Wood Pellet Boilers and Furnaces_Analysis_Jan 2018.xlsx. Pellet systems in existing homes with electric space heating are assumed to replace electric resistance systems with an efficiency of 1.00. Efficiency of existing wood heating systems based on professional judgment.

[15] Efficiencies for existing commercial LP and oil heating systems are a weighted average based on heating system data from Figure 47, and boiler and furnace efficiencies from Table 15: Cadmus, "2016 VT Business Sector Market Characterization and Assessment Study," April 2017. See file EVT_Central Wood Pellet Boilers and Furnaces_Analysis_Jan 2018.xlsx. Pellet systems in existing homes with electric space heating are assumed to replace electric resistance systems with an efficiency of 1.00. Efficiency of existing wood heating systems based on professional judgment.

[16] Efficiencies for new residential electric, LP, and oil heating systems are based on data from NMR Group, "Vermont Residential New Construction Baseline Study Analysis of On-Site Audits (Draft Report),"May 12, 2017. Boiler, furnace, and heat pump weightings are from page 47, Table 47, and equipment efficiencies are rom pages 49-50, Tables 50-52, NMR Group, "Vermont Residential New Construction Baseline Study Analysis of On-Site Audits (Draft Report),"May 12, 2017. Oil boilers, combined appliances, wood stoves and furnaces, pellet stoves, natural gas units, and heat pumps were removed from boiler and furnace weighting calculations. Values for Efficiency Vermont used. nBase (LP) is a weighted average based on the percentage of LP boilers and furnaces installed in new Vermont homes. Nbase (oil) is the efficiency of oil boilers.See file EVT_Central Wood Pellet Boilers and Furnaces_Analysis_Jan 2018.xlsx. Efficiency of new wood heating systems based on professional judgment.

[17] Efficiencies for new commercial LP and oil heating systems are an average of efficiencies for boilers <300,000 Btu/hr and furnaces <225,000 Btu/hr. Lowest efficiency available from AHRI database, except for oil furnaces <225 MBH and LP boilers <300 MBh, which were adjusted upward to better reflect the efficiencies available within those capacity bins. See reference file AHRI Boiler and Furnace Data.xlsx. Efficiency of existing wood heating systems based on professional judgment.

[18] Pellet boiler and furnace lifetime from Energy & Research Solutions, "Emerging Technologies Research Report," (report prepared for the Regional Evaluation, Measurement, and Verification Forum, February 13, 2013): page 9-20.

[19] Pellet boiler installed cost from Energy & Research Solutions, "Emerging Technologies Research Report," (report prepared for the Regional Evaluation, Measurement, and Verification Forum, February 13, 2013): page 9-2. Pellet furnace installed costs are assumed to be similar to pellet boiler costs.

[20] The baseline full installation cost for residential NC is based on the percentage of each heating system in new Vermont homes from NMR Group, "Vermont Residential New Construction Baseline Study Analysis of On-Site Audits (Draft Report)," Prepared by NMR Group for Vermont DPS, May 12, 2017: page 47, Table 47 (Efficiency Vermont data). Combined appliances and natural gas and pellet systems excluded. Full installation costs for baseline heating systems, except for cordwood furnaces, are the average of typical residential costs for years 2013 and 2020 from U.S. EIA, "Updated Buildings Sector Appliance and Equipment Costs and Efficiencies," November 2016. Cordwood furnaces are assumed to cost the same as pellet furnaces ($20,000). See EVT_Central Wood Pellet Boilers and Furnaces_Analysis_Jan 2018.xlsx for measure cost calculations.

[21] The baseline full installation cost for commercial NC is based on data from Cadmus, "2016 Vermont Business Sector Market Characterization and Assessment Study," April 30, 2017: page 178, Figure 129 ("All" data) and page 181, Figure 131. Boilers are divided between propane (44%) and wood (14%), and it is assumed that all furnaces are propane-fired. Full installation costs for baseline heating systems, except for cordwood boilers, are the average of typical residential costs for years 2013 and 2020 from U.S. EIA, "Updated Buildings Sector Appliance and Equipment Costs and Efficiencies," November 2016. Cordwood boilers are assumed to cost the same as pellet boilers ($20,000). See EVT_Central Wood Pellet Boilers and

Furnaces_Analysis_Jan 2018.xlsx for measure cost calculations.

[22] Pellet furnace and boiler O&M costs are assumed to be approximately the same as O&M costs for pellet stoves from U.S. EIA, "Updated Buildings Sector Appliance and Equipment Costs and Efficiencies," November 2016.

[23] The baseline O&M cost for existing homes is based on the percentage of each fuel type in existing Vermont homes. LP and oil systems are divided between boilers and furnaces. It is assumed that all wood heating systems are cordwood stoves. O&M costs for baseline heating systems, except for electric resistance, are from U.S. EIA, "Updated Buildings Sector Appliance and Equipment Costs and Efficiencies," November 2016. According to the report, O&M costs for electric resistance heating systems are negligible; $10 was assumed in these calculations. See EVT_Central Wood Pellet Boilers and Furnaces_Analysis_Jan 2018.xlsx for O&M cost calculations.

[24] The baseline O&M cost for residential NC is based on the percentage of each heating system in new Vermont homes from NMR Group, "Vermont Residential New Construction Baseline Study Analysis of On-Site Audits (Draft Report)," Prepared by NMR Group for Vermont DPS, May 12, 2017: page 47, Table 47 (Efficiency Vermont data). Combined appliances and natural gas and pellet systems excluded. O&M costs for baseline heating systems, except for cordwood furnaces, are from U.S. EIA, "Updated Buildings Sector Appliance and Equipment Costs and Efficiencies," November 2016. Cordwood furnace costs are assumed to be the same as costs for pellet boilers ($250). See EVT_Central Wood Pellet Boilers and Furnaces_Analysis_Jan 2018.xlsx for O&M cost calculations.

[25] The baseline O&M cost for existing buildings is based on the percentage of each fuel type in existing Vermont buildings. LP and oil systems are divided between boilers and furnaces. O&M costs for baseline heating systems, except for cordwood boilers and electric resistance, are from U.S. EIA, "Updated Buildings Sector Appliance and Equipment Costs and Efficiencies," November 2016. According to the report, O&M costs for electric resistance heating systems are negligible; $10 was assumed in these calculations. See EVT_Central Wood Pellet Boilers and Furnaces_Analysis_Jan 2018.xlsx for O&M cost calculations.

[26] The baseline O&M cost for commercial NC is based on data from Cadmus, "2016 Vermont Business Sector Market Characterization and Assessment Study," April 30, 2017: page 178, Figure 129 ("All" data) and page 181, Figure 131. Boilers are divided between propane (44%) and wood (14%), and it is assumed that all furnaces are propane-fired. O&M costs for baseline heating systems, except for cordwood boilers, are from U.S. EIA, "Updated Buildings Sector Appliance and Equipment Costs and Efficiencies," November 2016. Cordwood boiler costs are assumed to be the same as costs for pellet boilers ($250). See EVT_Central Wood Pellet Boilers and Furnaces_Analysis_Jan 2018.xlsx for O&M cost calculations.

Variable Speed Mini-Split Heat Pumps (Market Opportunity)

Measure Number:	VII-C-11 b
Portfolio:	EVT TRM Portfolio 2017-12
Status:	Active
Effective Date:	2018/1/1
End Date:	[None]
Program:	Existing Homes
End Use:	HVAC

Update Summary

This update includes results from the VT Heat Pump Evaluation which informs EFLH used in the savings algorithms.

Referenced Documents

- Navigant Consulting. (2013, January 16). Incremental Cost Study Phase Two Final Report.
- DHP 116 MOP LoadProfileAverager_final
- VT existing homeowner survey report - DRAFT
- Existing Heating System Efficiency Analysis
- Upstream EVT CCHP Program Data_Cost Analysis
- Upstream Program Data Natural Gas Territory Research
- Evaluation of Cold Climate Heat Pumps in Vermont
- EVT_CCHP MOP and Retrofit_2018_

Description

This measure claims savings for the installation of single and multi-head variable speed mini-split heat pumps. Heating and cooling savings are claimed as a market opportunity to account for the incremental savings of an efficient heat pump versus the installation of a baseline heat pump. Given the use of heat pumps as a supplemental heating source, the characterization assumes a standard mode of operation regardless of installation location.

Baseline Efficiencies

The baseline condition is assumed to be a new heat pump that is capable of providing heat using the heat pump cycle down to 5°F and meets the following minimum efficiencies:

Table 1 - Single Head Baseline Efficiency[1]

Equipment	HSPF	EER	SEER
Air-Source Heat Pump	8.6	9.8	15.6

Table 2 - Multi Head Baseline Efficiency[2]

Equipment	HSPF	EER	SEER
Air-Source Heat Pump	8.2	12	14.5

Efficient Equipment

To qualify for savings under this measure, the installed equipment must be a new mini-split heat pump that has a variable speed inverter-driven compressor, COP at 5°F ≥ 1.75 (at maximum capacity operation), and be capable of providing heat using the heat pump cycle down to -5°F. It must also meet or exceed the following efficiency criteria, per AHRI Standard 210-240-2008 for Unitary Air-Conditioning and Air-Source Heat Pump equipment.

Table 3 - Single-Head High Efficiency[3]

Equipment	HSPF	EER	SEER
Air-Source Heat Pump	10	12	20

Table 4 - Multi-Head High Efficiency

Equipment	HSPF	EER	SEER
Air-Source Heat Pump	10	12	17

Algorithms

Electric Demand Savings

Given the primary impact is on heating, demand impact is characterized for heating.

ΔkW	= (ΔkWh / EFLH) × New Construction Factor

Symbol Table

Electric Energy Savings

For the market opportunity measure, electric energy impacts are characterized as savings. Cooling impact uses full load cooling hours, and seasonal cooling efficiency. Heating impacts are characterized from EFLH derived from a metering analysis in the VT Heat Pump Evaluation.

ΔkWh	$= (\Delta kWh_{Cooling} + \Delta kWh_{Heating>=5F} - \Delta kWh_{Heating<5F}) \times$ New Construction Factor
$\Delta kWh_{Cooling}$	$= Q_{Cooling} \times EFLH_{Cooling} \times (1/SEER_{Baseline} - 1/SEER_{Efficient}) \times 1kWh/1000\ Wh$
$\Delta kWh_{Heating>5F}$	$= (Max\ Capacity_{5F}) \times EFLH \times (1/HSPF_{Baseline} \times 90\% - 1/HSPF_{Efficient} \times 90\%) \times 1\ kWh/1000\ Wh$
$\Delta kWh_{Heating<5F}$	$= \Delta MMBtu \times (1/COP_{<5F} - \%ElecHeat) \times 1\ kWh/\ 3412\ Btu$

Where:

%ElecHeat	=	= portion of homes with electric space heat = 2%[5] (deemed assumption for prescriptive savings)
%HeatSource	=	= Percent of existing heating systems using fuel type *j*[6169] = 51% for fuel oil = 26% for propane = 4% for Wood = 11% for Natural Gas = 8% for Electric
ΔkW	=	Total average winter coincident peak kW reduction (deemed assumption for prescriptive)
$\Delta kWh_{Cooling}$	=	= Cooling Energy Savings
$\Delta kWh_{Heating>=5F}$	=	= Heating Energy Savings above 5°F
$\Delta kWh_{Heating<5F}$	=	= Heating Penalty below above 5°F
ΔkWh	=	= Gross customer electric energy savings
$\Delta MMBtu$	=	MMBtu savings for each fuel type *j* (deemed assumption for prescriptive)
η_{Heatj}	=	= Heating system efficiency for fuel type *j* (deemed assumption for prescriptive)[6170] = 83% for fuel oil = 86% for propane = 66% for Wood/Other = 87% for Natural Gas =100% for Electric
90%	=	= Climatic adjustment to HSPF[6] (deemed assumption for prescriptive savings)
$COP_{<5F}$	=	= Assumed Coefficient of Performance below 5 degrees Fahrenheit =2.0[7]
$EFLH_{Cooling}$	=	= Equivalent Full Load Hours for heating = 239.81[8]
EFLH	=	Equivalent Full Load Hours for heating = 1,383[8]
$HSPF_{Baseline}$	=	= Heating Seasonal Performance Factor for Baseline equipment, Btu/Wh = 8.6[9](Single-head deemed assumption for prescriptive savings) = 8.2[10] (Multi-head deemed assumption for prescriptive savings)
$HSPF_{Efficient}$	=	= Heating Seasonal Performance Factor for Efficient equipment, Btu/Wh
$Max\ Capacity_{5F}$	=	Average Maximum Capacity (Btu/hr) of the CCHP at 5 degrees Fahreneheit[11]
New Construction Factor	=	Factor to account for better thermal envelope of new construction homes

= 99.25%[4]

$Q_{Cooling}$ = = nominal cooling capacity, Btu/hr

$Q_{Heating<5F,i}$ = = Maximum of rated heating capacity and estimated load in weather bin *i* below 5°F, MMBtu

$SEER_{Baseline}$ = = Seasonal Energy Efficiency Ratio for Baseline equipment, Btu/Wh

= 15.6[10](Single-head deemed assumption for prescriptive savings)

= 14.5[10](Multi-head deemed assumption for prescriptive savings)

$SEER_{Efficient}$ = = Seasonal Energy Efficiency Ratio for Efficient equipment, Btu/Wh

Load Shapes

116b Prescriptive Cold Climate Variable Speed Heat Pump (Market Opportunity)

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
116	Prescriptive Cold Climate Variable Speed Heat Pump (Market Opportunity)	Active	40.8 %	47.7 %	6.2 %	5.4 %	36.9 %	3.8 %

Net Savings Factors

Measures

SHRHPCVH	Cold climate single-head variable speed heat pump
SHRHPMHC	Cold climate multi head variable speed heat pump

Tracks [Base Track]

6032UPST [6032EPEP]	Upstream - Residential

Lifetimes

The expected measure life is assumed to be 15 years.[12]

Measure Cost

Single Head Measure Costs

The incremental installed measure cost of an efficient versus a baseline CCHP:

Nominal Equipment Capacity (Btu/hr)	Incremental Costs
6,000	$483
9,000	$493
12,000	$591
15,000	$588
18,000	$611
24,000	$693

Multi-Head Measure Cost[13]

Measure cost represents the market opportunity incremental installed cost of an efficient versus a baseline multi head CCHP.

Nominal Equipment Capacity (Btu/hr)	Incremental Cost
18,000	$411
24,000	$265
30,000	$1,343
36,000	$603
42,000	$787
48,000	$736

Savings Summary

Type	Capacity	ΔkWh Total	ΔkW
Single Zone	6,000	612.27	0.41
Single Zone	9,000	619.09	0.41

Single Zone	12,000	607.89	0.40
Single Zone	15,000	872.45	0.58
Single Zone	18,000	680.27	0.44
Single Zone	24,000	792.64	0.51
Multi Zone	18,000	680.74	0.44
Multi Zone	24,000	1,160.58	0.77
Multi Zone	30,000	1,323.92	0.89
Multi Zone	36,000	1,759.29	1.17
Multi Zone	42,000	2,268.67	1.54
Multi Zone	48,000	1,791.01	1.16

Footnotes

[1] Baseline single head CCHP efficiencies is derived from an analysis of installed heat pumps in Vermont from Vermont heat pump distributors. Review Efficiency Levels tab in EVT_CCHP MOP and Retrofit_2018_.xlsx.

[2] Based on November 2014 TAG Agreement. Review of mutli-head CCHP shows HSPF average is below single-head units.

[3] High efficiencies for single and multi zone cold climate heat pumps are derived from various sources. HSPF rating based on NEEP criteria, refer to Cold Climate Air-source Heat Pump Specification-Version 2.0Jan2017 (1).pdf. EER rating based on ENERGY STAR specifications for air source heat pumps, refer to https://www.energystar.gov/products/heating_cooling/heat_pumps_air_source/key_product_criteria.

[4] See EVT_CCHP MOP and Retrofit_2018_.xlsx, New Construction tab for detailed analysis

[5] Percentage of heating fuel types in existing Vermont homes from NMR Group, "Survey Analysis of Owners of Existing Homes in Vermont (Draft)" December 5, 2016: page 29, Table 38 (Statewide Data). Kerosene, coal, and solar were excluded. The report states that "all nine respondents who use electricity as their primary heating fuel reported that they have electric resistance baseboard rather than an electric heat pump."

[6] Energy & Resource Solutions. (2014). *Emerging Technology Program Primary Research – Ductless Heat Pumps.* Lexington, MA: NEEP Regional EM&V Forum. Table 1-2. Page 5.

[7] Conservative average of low temperature COP according to manufacturer's engineering documents.

[8] EFLH is calculated in an analysis of heat pump metered data. The partial load of each heat pump is summed up through the heating season, and taken as an average across all units metered. This analysis can be found on the EFLH Calculator tab in the EVT_CCHP MOP and Retrofit_2018_.xlsx.

[9] Per TAG Agreement

[10] See Baseline Efficiency section

[11] This value is derived as an average of capacities that the CCHP can provide at 5 degrees Fahrenheit. These are from the engineering spec sheets of the CCHPs that are on the EVT QPL.

[12] California DEER Effective Useful Life values, updated October 10, 2008. Various sources range from 12 to 20 years, DEER represented a reasonable mid-range.

[13] Navigant Consulting Inc. (2013). Incremental Cost Study Phase Two Final Report. Burlington, MA: NEEP Evaluation, Measurement, and Verification Forum. Review Costs tab of EVT_CCHP MOP and Retrofit_2018_.xlsx.

Variable Speed Mini-Split Heat Pumps (Retrofit)

Measure Number:	VII-C-12 b
Portfolio:	EVT TRM Portfolio 2017-12
Status:	Inactive
Effective Date:	2018/1/1
End Date:	2018/12/31
Program:	Existing Homes
End Use:	HVAC

Update Summary

This update includes results from the VT Heat Pump Evaluation which informs EFLH used in the savings algorithms.

Referenced Documents

- Navigant Consulting. (2013, January 16). Incremental Cost Study Phase Two Final Report.
- DHP 123 Retrofit LoadProfileAverager_final
- VT existing homeowner survey report - DRAFT
- Existing Heating System Efficiency Analysis
- Upstream EVT CCHP Program Data_Cost Analysis
- Upstream Program Data Natural Gas Territory Research
- Evaluation of Cold Climate Heat Pumps in Vermont
- EVT_CCHP MOP and Retrofit_2018_

Description

This measure claims savings for the installation of single and multi-head variable speed mini-split heat pumps. Heating savings are claimed as a retrofit of the building's existing heating system to account for the heating offset where a heat pump is used to provide supplemental heat. The existing fuel system savings are allocated as both fossil fuel and electric savings to account for the assumed mix of fossil fuel and electric resistance heating of program participants. For this case, the added electric load associated with the heat pump is counted as a penalty for both heating and cooling. This measure is in connection with the Market Opportunity characterization for single and multi-head variable speed mini-split heat pumps.

Baseline Efficiencies

The baseline condition for a retrofit is assumed to be the existing residential fossil fuel heating system.

Table 1 - Baseline Efficiency

Existing Fuel	Average System Efficiency[1]
Fuel Oil	83%
Natural Gas	87%
Propane	86%
Wood	66%
Electric	100%

Efficient Equipment

The assumed efficient condition represents the minimum efficiency for Variable Speed Mini-Split Heat Pumps in the Vermont marketplace. There is also a seperate market opportunity characterization for Variable Speed Mini-Split Heat Pumps that claims the savings associated with the incremental efficiency improvements for heat pumps that provide higher levels of efficiency.

Table 2- Single Zone High Efficiency[2]

Equipment	HSPF	EER	SEER
Air-Source Heat Pump	8.6	9.8	15.6

Table 3- Multi-Head High Efficiency[3]

Equipment	HSPF	EER	SEER
Air-Source Heat Pump	8.2	12	14.5

Algorithms

Electric Demand Savings

Given the primary impact is on heating, demand impact is characterized for heating.

ΔkW $= (\Delta kWh / EFLH) \times \text{New Construction Factor}$

Symbol Table

Electric Energy Savings

Electric energy impacts are characterized as penalties to account for the added electric load of the heat pump. Cooling and heating impacts are characterized using equivalent full load hours (EFLH) and seasonal efficiency ratings. Both heating and cooling EFLH are derived from metering analyses in the Vermont Heat Pump Evaluation. The heating EFLH analysis is based on maximum 5 degree capacity for the heat pumps. Adjustments are made to discount the savings to account for the heat pump installation in new construction application where no baseline system exists.

$$\Delta kWh_{Heating>5F} = ((- \text{Max Capacity}_{5F} \times EFLH \times 1/ HSPF) / 1000 + (- \text{Nominal Capacity} \times EFLH_{Cooling} \times (1/SEER_{Efficient}) \times 1 / 1000)) \times \text{New Construction Factor}$$

Symbol Table

Fossil Fuel Savings

Retrofit fossil fuel savings are taken for operation of the heat pump offsetting fuel use from the home’s existing heating system.

$$\Delta MMBtu = (\text{Max Capacity}_{5F} \times EFLH) / 1{,}000{,}000 \times \%HeatSource/\eta_{Heatj} \times \text{New Construction Factor}$$

Where:

%HeatSource = = Percent of existing heating systems using fuel type *j*[7]

= 51% for fuel oil

= 26% for propane

= 4% for Wood

= 11% for Natural Gas

= 8% for Electric

ΔkW = total average winter coincident peak kW increase

$\Delta kWh_{Heating>5F}$ = = Heating Energy Savings above 5°F

ΔkWh = = total net kWh penalties for heating and cooling (deemed assumption for prescriptive savings, based on size category)

ΔMMBtu = = MMBtu savings for each fuel type *j* (deemed assumption for prescriptive)

η_{Heatj} = = Heating system efficiency for fuel type *j*[8] (deemed assumption for prescriptive)

= 83% for fuel oil

= 86% for propane

= 66% for Wood/Other

= 87% for Natural Gas

=100% for Electric

$EFLH_{Cooling}$ = = Equivalent Full Load Hours for heating

= 239.81[4]

EFLH = = Equivalent Full Load Hours for heating

= 1,383[4]

HSPF = = Heating Seasonal Performance Factor for new equipment, Btu/Wh

= 8.6 (Single-Head)

= 8.2 (Multi-Head)

Max Capacity_{5F} = =Average Maximum Capacity (Btu/hr) of the CCHP at 5 degrees Fahreneheit[6]

New Construction Factor = = Factor to account for better thermal envelope of new construction homes

= 99.25%[5]

Nominal Capacity = = Nominal Capacity of the CCHP (Btu/hr)

$SEER_{Efficient}$ = = Seasonal Energy Efficiency Ratio for Efficient equipment, Btu/Wh

SEER = = Seasonal Energy Efficiency Ratio for new equipment, Btu/Wh

= 15.6 (Single-Head)

= 14.5 (Multi-Head)

Load Shapes

123a Prescriptive Cold Climate Variable Speed Heat Pump (Retrofit)

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
123	Prescriptive Cold Climate Variable Speed Heat Pump (Retrofit)	Active	41.6 %	48.6 %	5.2 %	4.6 %	36.9 %	5.5 %

Net Savings Factors

Measures

SHRHPCVH	Cold climate single-head variable speed heat pump
SHRHPMHC	Cold climate multi head variable speed heat pump

Tracks [Base Track]

6032UPST [6032EPEP]	Upstream - Residential

Lifetimes

The expected measure life is assumed to be 15 years.[9]

Measure Cost

Table 4 - Single-Head Measure Costs[10]

Nominal Equipment Capacity (Btu/hr)	Retrofit Costs
6,000	$2,759.80
9,000	$2,763.71
12,000	$2,761.05
15,000	$2,894.48
18,000	$3,132.36
24,000	$3,426.49

Table 5 - Multi-Head Measure Cost

Nominal Equipment Capacity (Btu/hr)	Retrofit Cost
18,000	$3,494.93
24,000	$3,991.69
30,000	$3,754.15
36,000	$4,342.63
42,000	$5,036.26
48,000	$5,481.42

Savings Summary

Type	Capacity	kWh Penalty	kW Penalty	ΔMMBtuoil	ΔMMBtunatural gas	ΔMMBtupropane	ΔMMBtuwood
Single Zone	6,000	(1,493.77)	(1.08)	7.30	1.54	3.65	0.65
Single Zone	9,000	(1,805.86)	(1.31)	8.69	1.83	4.35	0.77
Single Zone	12,000	(2,051.28)	(1.48)	9.73	2.05	4.87	0.86
Single Zone	15,000	(2,891.69)	(2.09)	13.87	2.92	6.94	1.23
Single Zone	18,000	(2,990.76)	(2.16)	14.15	2.98	7.07	1.26
Single Zone	24,000	(3,753.36)	(2.71)	17.65	3.72	8.82	1.57
Multi Zone	18,000	(2,873.75)	(2.08)	12.84	2.70	6.42	1.14
Multi Zone	24,000	(3,914.81)	(2.83)	17.53	3.69	8.76	1.56
Multi Zone	30,000	(4,864.97)	(3.52)	21.77	4.59	10.88	1.93
Multi Zone	36,000	(6,760.13)	(4.89)	30.71	6.47	15.35	2.73
Multi Zone	42,000	(8,785.04)	(6.35)	40.30	8.49	20.15	3.58
Multi Zone	48,000	(6,509.66)	(4.71)	28.48	6.00	14.24	2.53

Footnotes

[1] Average efficiency of existing homes in Vermont from homes surveyed in NMR Group's 2016 on site surveying. Review Existing Heating tab in analysis document: EVT_CCHP MOP and Retrofit_2018_.xlsx.

[2] Minimum available efficiencies are derived from an analysis of installed heat pumps in Vermont from distributors participating in the upstream program. Review Efficiency Levels tab in CCHP Sales Baseline Analysis.xlsx.

[3] Based on November 2014 TAG Agreement. Review of mutli-head CCHP shows HSPF average is below single-head units.

[4] EFLH is calculated in an analysis of heat pump metered data. This analysis can be found on the EFLH Calculator tab in the EVT_CCHP MOP and Retrofit_2018_.xlsx.

[5] See EVT_CCHP MOP and Retrofit_2018_.xlsx, New Construction tab for detailed analysis

[6] This value is derived as an average of maximum capacity that the cold climate heat pump can provide at 5 degrees Fahrenheit based on manufacturer's specifications for qualified equipment. Review of these efficiencies can be found on the Current Product List tab of the analysis document: EVT_CCHP MOP and Retrofit_2018_.xlsx.

[7] Percentage of heating fuel types in existing Vermont homes based on analysis of installed cold climate heat pumps in Efficiency Vermont's upstream program. Analysis can be found in Upstream Program Data Natural Gas Territory Research.xlsx.

[8] Average efficiency of existing homes in Vermont from homes surveyed in NMR Group's 2016 on site surveying. Review Existing Heating tab of analysis document: EVT_CCHP MOP and Retrofit_2018_.xlsx.

[9] California DEER Effective Useful Life values, updated October 10, 2008. Various sources range from 12 to 20 years, DEER represented a reasonable mid-range.

[10] Cost analysis of Vermont installed Cold Climate Heat Pumps through Efficiency Vermont’s program. Distributor reported costs analyzed in Upstream EVT CCHP Program Data_Cost Analysis.xlsx. *Labor costs are assumed to be identical for all minisplit systems @ $1,763/unit (NEEP Incremental Cost Study, 2012). There has been no evidence in studies or reports that O&M Costs should be considered for this measure.

Centrally Ducted Air Source Heat Pump (Market Opportunity)

Measure Number:	VII-C-13 a
Portfolio:	EVT TRM Portfolio 2018-04
Status:	Active
Effective Date:	2018/1/1
End Date:	[None]
Program:	Existing Homes
End Use:	HVAC

Update Summary

New measure

Referenced Documents

- VT SF Existing Homes Onsite Report - DRAFT 122117
- New York Standard Approach for Estimating Energy Savigns from Energy Efficiency Programs 2016
- Federal Efficienct Standards (CFR-2012-title10-vol3-sec430-32)
- NEEP Air Source Heat Pump QPL
- GDS Associates_Measure Life Report_Jun 2007
- EVT_Centrally Ducted ASHP_Analysis_Mar 2018_v4

Description

This measure claims savings for the installation of centrally ducted air source heat pumps. Heating and cooling savings are claimed as a market opportunity to account for the incremental savings of an efficient heat pump versus the installation of a less efficient baseline heat pump. The installed air source heat pump must meet Energy Star efficiency standards and have a capacity of <= 65,000 Btu/hr. The characterization assumes a standard mode of operation regardless of installation, location, or application - residential or commercial. The characterization of this measure assumes a midstream program delivery method.

Baseline Efficiencies

The baseline condition is assumed to be a new heat pump that is capable of providing heat using the heat pump cycle and meets the following minimum efficiencies:

Table 1 - Residential Baseline Efficiency[1]

Equipment	HSPF	SEER
Air-Source Heat Pump	8.2	14

Table 2 - Commercial Baseline Efficiency[2]

Equipment	HSPF	SEER
Air-Source Heat Pump	8.1	14

Efficient Equipment

To qualify for savings under this measure, the installed equipment must be a centrally ducted air source heat pump listed on NEEP's Qualified Products List, COP at 5°F ≥ 1.75 (at maximum capacity operation), and be capable of providing heat using the heat pump cycle down to -5°F. It must also meet or exceed the following efficiency criteria, per AHRI Standard 210-240-2008 for Unitary Air-Conditioning and Air-Source Heat Pump equipment.

Table 3 - Residential and Commercial High Efficiency[3]

Equipment	HSPF	SEER
Air-Source Heat Pump	10	15.6

Algorithms

Electric Demand Savings

ΔkW $= kBtuh \times (1/HSPF_{Baseline} - 1/HSPF_{Efficient})$

Symbol Table

Electric Energy Savings

ΔkWh $= kBtuh \times (1/HSPF_{Baseline} - 1/HSPF_{Efficient}) \times EFLH_{Heating} + tons \times (12/SEER_{Baseline} - 12/SEER_{Efficient}) \times EFLH_{Cooling}$

Table 4 - Residential Savings Summary[9]

Average Cooling Capacity Bin	Capacity Range	kWh	kW
18,000	<=21,000	319	0.11
24,000	>21,000 and <=27,000	738	0.39
30,000	>27,000 and <=33,000	1,345	0.79
36,000	>33,000 and <=39,000	1,210	0.66
42,000	>39,000 and <=45,000	1,930	1.13
48,000	>45,000	2,417	1.45

Table 5 - Commercial Savings Summary[9]

Average Cooling Capacity Bin	Capacity Range	kWh	kW
18,000	<=21,000	383	0.12
24,000	>21,000 and <=27,000	712	0.42
30,000	>27,000 and <=33,000	1,193	0.83
36,000	>33,000 and <=39,000	1,134	0.70
42,000	>39,000 and <=45,000	1,695	1.18
48,000	>45,000	2,074	1.51

Table 6 - Deemed Values

Average Cooling Capacity Bin	Heating Capacity (kBtuh)	Average Cooling Capacity (tons)	$HSPF_{Efficient}$	$SEER_{Efficient}$
18,000	9.7	1.5	9.0	21.0
24,000	19.5	2.0	9.8	19.0
30,000	31.2	2.5	10.3	18.5
36,000	28.3	3.0	10.1	18.8
42,000	33.4	3.5	11.3	18.7
48,000	39.4	4.0	11.7	18.3

Symbol Table

Fossil Fuel Savings

Where:

ΔkW = Total average summer coincident peak kW reduction (deemed assumption for prescriptive)

ΔkWh = Gross customer electric energy savings

$EFLH_{Cooling}$ = Equivalent full load cooling hours
375 hours (residential)[4]
591 hours (commercial)[5]

$EFLH_{Heating}$ = Equivlaent full load heating hours
1,462 hours (residential)[6]
1,062 hours (commercial)[5]

$HSPF_{Baseline}$ = Heating Seasonal Performance Factor for Baseline equipment, Btu/Wh
see table 1 and 2 (based on federal efficiency standards and VT CBES 2015)

$HSPF_{Efficient}$ = Heating Seasonal Performance Factor for Efficient equipment, Btu/Wh[7]
see table 6 for more details

kBtuh = Average rated heating capacity[7]
see table 6 for more details

$SEER_{Baseline}$ = Seasonal Energy Efficiency Ratio for Baseline equipment, Btu/Wh
see table 1 and 2 (based on federal efficiency standards and VT CBES 2015)

$SEER_{Efficient}$ = Seasonal Energy Efficiency Ratio for Efficient equipment, Btu/Wh[8]
see table 6 for more details

Load Shapes

116b Prescriptive Cold Climate Variable Speed Heat Pump (Market Opportunity)

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
116	Prescriptive Cold Climate Variable Speed Heat Pump (Market Opportunity)	Active	40.8 %	47.7 %	6.2 %	5.4 %	36.9 %	3.8 %

Net Savings Factors

Measures

SHRDASHP	Centrally Ducted Air Source Heat Pump - Heat Pump Baseline
SHFDASHP	Centrally Ducted Air Source Heat Pump - Fuel-fired Baseline

Tracks [Base Track]

6013PRES [is base track]	Pres Equip Rpl
6036RETR [is base track]	Res Retrofit

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Pres Equip Rpl	6013PRES	SHRDASHP	1.00	1.00
Res Retrofit	6036RETR	SHRDASHP	0.90	1.00
Pres Equip Rpl	6013PRES	SHFDASHP	1.00	1.00
Res Retrofit	6036RETR	SHFDASHP	0.90	1.00

Lifetimes

The expected measure life is assumed to be 18 years.[10]

Measure Cost

Table 7 - Residential and Commercial Measure Cost[11]

Measure cost represents the market opportunity incremental installed cost of an efficient versus a baseline air source heat pump.

Equipment Capacity (Btu/hr)	Incremental Cost
18,000	$2,069
24,000	$1,988
30,000	$2,226
36,000	$2,860
42,000	$3,245
48,000	$3,388

Footnotes

[1] The residential baseline efficiencies are sourced from the Federal Efficiency Standards as of 1/1/2015 for single and packaged central air conditioners and heat pumps. Please either find the ruling attached (Federal Efficient Standards (CFR-2012-title10-vol3-sec430-32)) or at the following location: https://www.gpo.gov/fdsys/pkg/CFR-2012-title10-vol3/pdf/CFR-2012-title10-vol3-sec430-32.pdf

[2] The commercial baseline efficiency values are sourced from the VT CBES 2015 for the minimum efficiency requirements for electrically operated unitary and applied heat pumps: https://codes.iccsafe.org/public/chapter/content/7862/

[3] Cold climate air source heat pump, per NEEP's Qualified Products List, last updated on January 18, 2018. Please either find it attached (NEEP Air Source Heat Pump QPL) or at the following location: http://www.neep.org/initiatives/high-efficiency-products/emerging-technologies/ashp/cold-climate-air-source-heat-pump

[4] Residential EFLH Cooling is estimated by applying a 25% adjustment factor to U.S. Climate Cooling Region 2 Full Load Hours of 500 hours to 375 hours.

[5] The commercial EFLH heating and cooling hours are sourced from the New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs, version 4, January 2017 (New York TRM). Hours are based on an average between the city of Massena and Albany; with it being an average between old and new building types and weighted by small commercial buildings.

[6] Residential EFLH Heating is estimated from an 8,760 equivalent full load hours analysis. The analysis assumes the heating systems provide heating below 50°F, except in summer months May to August, and estimates savings based on incremental efficiency down to the lower heating limit of the baseline system at 5°F. The analysis assumes the heat pump provides heating based on its rated capacity (up to the estimated load) for each weather bin.

[7] The heating capacity and efficient heating HSPF is sourced from NEEP's Qualified Products List for centrally ducted heat pumps rated at varying temperatures (47°F, 17°F, and 5°F outdoor wet bulb temperature) and represent a weighted average BIN approach based on Burlington, VT weather data and capacities.

[8] The efficient cooling SEER and average cooling capacity is sourced from the NEEP Qualified Products List and represent a weighted average across all capacities

[9]	Replacement scenario is defined as a MOP, so the baseline equipment is a less efficient heat pump meeting the minimum federal efficieny standards. Savings are being claimed on both the heating and cooling system. The peak demand savings for winter is being used as the primary demand savings. Please note that the NEEP Qualified Products List did not have centrally ducted air source heat pumps in the 42,000 capacity bin, so instead of using actual equipment values for the 42,000 capacity bin, a trend analysis was performed based on the other bins in order to calculate prescriptive savings.
[10]	"Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures", GDS Associates, June 2007.
[11]	Mid-Atlantic Technical Reference Manual, version 7.0, May 2017

Centrally Ducted Air Source Heat Pump (Retrofit)

Measure Number:	VII-C-13 d
Portfolio:	EVT TRM Portfolio 2018-12
Status:	Active
Effective Date:	2018/1/1
End Date:	[None]
Program:	Existing Homes
End Use:	HVAC

Update Summary

New measure

Removed natural gas heating savings from the mixed fossil fuel baseline.

Referenced Documents

- VT SF Existing Homes Onsite Report - DRAFT 122117
- New York Standard Approach for Estimating Energy Savigns from Energy Efficiency Programs 2016
- NEEP Air Source Heat Pump QPL
- Mid_Atlantic_TRM_V7_FINAL
- GDS Associates_Measure Life Report_Jun 2007
- EVT_Centrally Ducted ASHP_Analysis_Mar 2018_v5

Description

This measure claims savings for the installation of centrally ducted air source heat pumps. Heating savings are claimed as a retrofit of the home's existing fossil fuel heating system, and accounts for the fossil fuel system providing supplemental heat at low outdoor air temperatures. As only 2% of Vermont homes utilize central air conditioning[1], for this retrofit replacement scenario, the added electrical load associated with the heat pump is counted as a penalty for both heating and cooling. The installed air source heat pump must meet Energy Star efficiency standards and have a capacity of <= 65,000 Btu/hr. The characterization assumes a standard mode of operation regardless of installation, location, or application - residential or commercial. The installed air source heat pump is intended to supplement the existing fossil fuel heating system and not completely replace it, and the characterization of this measure assumes a midstream program delivery method.

This measure is in connection with the Market Opportunity characterization for centrally ducted air source heat pumps. As both characterizations, retrofit and market opportunity, will be implemented in tandem through an upstream delivery mechanism, the actual replacement scenario will be unknown and savings will be claimed for both measures to make sure they are additive and do not overlap.

Baseline Efficiencies

The baseline condition is assumed to be the existing fossil fuel furnace. Sites with natural gas fossil fuel systems are excluded from participation in this measure and as a result, are not included in the characterization.

Table 1 - Residential Baseline Efficiency[2]

Existing Fuel Type	Average Furnace Efficiency
Fuel Oil	81.3%
Propane	87.4%

Table 2 - Commercial Baseline Efficiency[3]

Existing Fuel Type	Average Furnace Efficiency
Fuel Oil	82.0%
Propane	86.0%

Table 3 - Central Air Conditioning Baseline Efficiency

Sector	SEER
Residential[1]	11.4
Commercial[4]	11.7

Efficient Equipment

The installed heat pump is assumed to meet the efficiencies outlined in table 4.

Table 4 - Residential and Commercial High Efficiency

Equipment	HSPF	SEER
Residential Air-Source Heat Pump	8.2	14
Commercial Air-Source Heat Pump	8.1	14

Algorithms

Electric Demand Savings

$\Delta kW_{Penalty}$	$= kBtuh \times (-1/HSPF_{Efficient})$

Symbol Table

Electric Energy Savings

$\Delta kWh_{Penalty}$	$= kBtuh \times (-1/HSPF_{Efficient}) \times EFLH_{Heating} + \{(tons \times (12/SEER_{Baseline} - 12/SEER_{Efficient}) \times \%CAC) - (tons \times (12/SEER_{Efficient}) \times (1 - \%CAC))\} \times EFLH_{Cooling}$

Symbol Table

Fossil Fuel Savings

$\Delta MMBtu$	$= (kBtuh \times EFLH_{Heating} / \eta_{Efficiency}) / 1000$

Where:

%CAC	=	Percent of existing homes in Vermont with central air conditioning = 2%[7]
$\Delta kW_{Penalty}$	=	Total average summer coincident peak kW penalty (deemed assumption for prescriptive)
$\Delta kWh_{Penalty}$	=	Gross customer electric energy penalty (deemed assumption for prescriptive)
$\Delta MMBtu$	=	MMBtu savings for each fuel type (deemed assumption for prescriptive)
$\eta_{Efficiency}$	=	Efficiency of the fossil fuel heating system see tables 1 and 2 for more details
$EFLH_{Cooling}$	=	Equivalent full load cooling hours 375 hours (residential)[8] 591 hours (commercial)[9]
$EFLH_{Heating}$	=	Equivalent full load heating hours 1,462 hours (residential)[10] 1,062 hours (commercial)[9]
$HSPF_{Efficient}$	=	Heating Seasonal Performance Factor for Efficient equipment, Btu/Wh see table 4 for more details
kBtuh	=	Average rated heating capacity[11] see table 8 for more details
$SEER_{Baseline}$	=	Seasonal Energy Efficiency Ratio for Baseline equipment, Btu/Wh see table 3 for more details
$SEER_{Efficient}$	=	Seasonal Energy Efficiency Ratio for Efficient equipment, Btu/Wh see table 4 for more details
tons	=	Average cooling capacity[12] see table 8 for more details

Table 5 - Furnace Type Distribution[5]

Fuel Type	Residential	Commercial
Fuel Oil	65.5%	37.8%
Propane	34.5%	62.2%

Table 6 - Residential Savings Summary[6]

Average Capacity Bin	Capacity Range	kWh	kW	ΔMMBtu Oil	ΔMMBtu Propane
18,000	<=21,000	-2,192	-1.18	11.4	5.6
24,000	>21,000 and <=27,000	-4,110	-2.38	23.0	11.3
30,000	>27,000 and <=33,000	-6,354	-3.81	36.8	18.0
36,000	>33,000 and <=39,000	-5,995	-3.46	33.4	16.4
42,000	>39,000 and <=45,000	-7,050	-4.07	39.3	19.3

48,000	>45,000	-8,272	-4.80	46.4	22.7

Table 7 - Commercial Savings Summary[6]

Average Capacity Bin	Capacity Range	kWh	kW	ΔMMBtu Oil	ΔMMBtu Propane
18,000	<=21,000	-2,007	-1.19	4.7	7.4
24,000	>21,000 and <=27,000	-3,549	-2.41	9.6	15.0
30,000	>27,000 and <=33,000	-5,330	-3.86	15.3	24.0
36,000	>33,000 and <=39,000	-4,198	-3.50	13.9	21.8
42,000	>39,000 and <=45,000	-6,106	-4.12	16.4	25.6
48,000	>45,000	-7,136	-4.86	19.3	30.2

Table 8 - Deemed Values

Average Capacity Bin	Heating Capacity (kBtuh)	Average Cooling Capacity (tons)
18,000	9.7	1.5
24,000	19.5	2.0
30,000	31.2	2.5
36,000	28.3	3.0
42,000	33.4	3.5
48,000	39.4	4.0

Load Shapes

123a Prescriptive Cold Climate Variable Speed Heat Pump (Retrofit)

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
123	Prescriptive Cold Climate Variable Speed Heat Pump (Retrofit)	Active	41.6 %	48.6 %	5.2 %	4.6 %	36.9 %	5.5 %

Net Savings Factors

Measures

SHRDASHP	Centrally Ducted Air Source Heat Pump - Heat Pump Baseline
SHFDASHP	Centrally Ducted Air Source Heat Pump - Fuel-fired Baseline

Tracks [Base Track]

6013PRES [is base track]	Pres Equip Rpl
6036RETR [is base track]	Res Retrofit

Lifetimes

The expected measure life is assumed to be 18 years.[13]

Measure Cost

Table 8 - Residential and Commercial Measure Cost[14]

The incremental retrofit cost is the full equipment cost of the air source heat pump.

Equipment Capacity (Btu/hr)	Incremental Cost
18,000	$823
24,000	$1,097
30,000	$1,371
36,000	$1,645
42,000	$1,919
48,000	$2,193

Footnotes

[1] "Vermont Single-Family Existing Homes Onsite Report", NMR Group, December 2017 (page 49)

[2] Average residential furnace efficiency of existing homes in Vermont, as sourced from homes surveyed in NMR Group's 2017 on site surveying; "Vermont Single-Family Existing Homes Onsite Report", NMR Groupt, December 2017 (page 45)

[3] Mean observed efficiency for warm air fossil fuel furnaces for existing commercial buildings, as sourced from "Vermont Market Assessment Report",

Cadmus (page 65). The efficiency of propane furnaces was not included in the report. In order to incoporate the propane fuel type into the analysis, opted to use the combined efficiency values for propane boilers and furnaces, as sourced from the data for the same report.

[4] The baseline cooling efficiency for commercial central air conditioning systems is based on an aggregation of all cooling systems under 5.5 tons in commercial buildings, as sourced from the "Vermont Market Assessment Report", Cadmus, April 2017

[5] As the program delivery method for this measure is midstream, the intention is the fuel type of the furnace being off-set will be unknown, and this necissitates a fuel type distribution of furnaces being impacted by this measure. The MMBtu energy savings are thus split across the different fuel types based on their saturation in the state of Vermont and is dependant on the building stock and sector. Sites utilizing natural gas fuel are excluded from participating in this measure and are removed from consideration in this characterization. The derivation for the fuel type distribution and the accompanying sources can be viewed in detail in the "EVT_Centrally Ducted ASHP_Analysis_Mar 2018_v5.xlsx"

[6] Replacement scenario is defined as a RET, so the baseline equipment is the existing fossil fuel heating system (electric resistance heating was not considered a viable baseline for this measure). Fossil fuel savings are being claimed for the heating system with an electric penalty on both the heating and cooling sytem due to the installation of the heat pump. The peak demand savings for winter is being used as the primary demand savings. Please note that the NEEP Qualified Products List did not have centrally ducted air source heat pumps in the 42,000 capacity bin, so instead of using actual equipment values for the 42,000 capacity bin, a trend analysis was performed based on the other bins in order to calculate prescriptive savings.

[7] 2% of Vermont single-family houses have central air conditionings, as sourced from the "VT SF Existing Homes Onsite Report", December 2017, NMR Group, page 49

[8] Residential EFLH Cooling is estimated by applying a 25% adjustment factor to U.S. Climate Cooling Region 2 Full Load Hours of 500 hours to 375 hours.

[9] The commercial EFLH heating and cooling hours are sourced from the New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs, version 4, January 2017 (New York TRM). Hours are based on an average between the city of Massena and Albany; with it being an average between old and new building types and weighted by small commercial buildings.

[10] Residential EFLH Heating is estimated from an 8,760 equivalent full load hours analysis. The analysis assumes the heating systems provide heating below 50°F, except in summer months May to August, and estimates savings based on incremental efficiency down to the lower heating limit of the baseline system at 5°F. The analysis assumes the heat pump provides heating based on its rated capacity (up to the estimated load) for each weather bin.

[11] The heating capacity is sourced from NEEP's Qualified Products List for centrally ducted heat pumps rated at varying temperatures (47°F, 17°F, and 5°F outdoor wet bulb temperature) and represent a weighted average BIN approach based on Burlington, VT weather data and capacities.

[12] The average cooling capacity is sourced from the NEEP Qualified Products List and represent a weighted average across all capacities

[13] "Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures", GDS Associates, June 2007.

[14] Mid-Atlantic Technical Reference Manual, version 7.0, May 2017

Air to Water Heat Pump

Measure Number: VII-C-14 b
Portfolio: EVT TRM Portfolio 2018-12
Status: Active
Effective Date: 2018/1/1
End Date: [None]
Program: Existing Homes
End Use: HVAC

Update Summary

New measure.

Removed natural gas heating savings from the mixed fossil fuel baseline.

Referenced Documents

- NEEP Incremental Cost Study Report 2011
- VT Res Baseline SFNC Onsite report - DRAFT 051217
- VT SF Existing Homes Onsite Report - DRAFT 122117
- New York Standard Approach for Estimating Energy Savigns from Energy Efficiency Programs 2016
- GDS Associates_Measure Life Report_Jun 2007
- NEEP Incremental Cost Study Phase II_Jan 2013
- Cadmus_VT Business Sector Market Characterization_Apr 2017
- NREL_Optimizing Hydronic System Performance_Oct 2013
- EVT_Air to Water Heat Pump Analysis_v9

Description

This measure claims savings for the installation of an air to water heat pump. Heating savings are claimed on the home’s auxiliary fossil fuel hydronic heating system and accounts for the fossil fuel system providing supplemental heat at low outdoor air temperatures. The electric penalty is the result of the air to water heat pump operating in heating mode, down to 0°F outdoor air temperature, at which point the auxiliary heating system assumes the full heating load.

The heat pump extracts low temperature heat from outside air and transfers it to a fluid steam to be used by a hydronic distribution system. The characterization assumes a standard mode of operation regardless of installation, location, or application – residential or commercial. The installed air to water heat pump is intended to supplement the existing fossil fuel heating system and not completely replace it, and the characterization of this measure assumes a midstream program delivery method.

Air to water heat pumps are categorized as low temperature hydronic heating systems and typically operate at a maximum supply water temperature of 120°F. If an air to water heat pump is retrofitted on an existing high temperature hydronic fossil fuel system, additional emitters are required in order to meet the design load of the building. The minimum qualification criteria for an air to water heat pump is to generate 110°F supply water at an outdoor temperature of 5°F with a COP of 1.7 or greater.

Baseline Efficiencies

For retrofit replacement scenarios, the baseline condition is assumed to be the existing fossil fuel hydronic heating system. For market opportunities, the baseline condition is assumed to be a code compliant fossil fuel hydronic heating system. Sites with natural gas fossil fuel systems are excluded from participation in this measure and as a result, are not included in the characterization.

Table 1 - Residential Baseline Efficiency

Replacement Scenario	Equipment Fuel Type	Average Boiler Efficiency
RET[1]	Fuel Oil	83.6%
	Propane	87.8%
	Wood	65.0%
MOP[2]	Fuel Oil	86.3%
	Propane	93.4%
	Wood	75.0%

Table 2 - Commercial Baseline Efficiency

Replacement Scenario	Equipment Fuel Type	Average Boiler Efficiency
RET[3]	Fuel Oil	85.0%
	Propane	87.0%
	Wood	65.0%
	Fuel Oil	80.0%

MOP[4]	Propane	80.0%
	Wood	75.0%

Efficient Equipment

The installed heat pump is assumed to meet the efficiency outlined in table 3, which represents the average efficiency of qualifying equipment used in the energy savings algorithm. The values in the following table are a result of weighted averages of available equipment from local distributors binned across Burlington, VT weather data down to an outdoor air temperature of 0°F, averaged across 100°F, 110°F, and 120°F supply water temperatures.

Table 3 - Residential and Commercial Air to Water Heat Pump Efficiency

Equipment	Rating Heating Capacity Bin (Tons)	COP
Air to Water Heat Pump	2	2.75
	3	2.78
	4	2.91
	Overall Average	2.83

Algorithms

Electric Demand Savings

Given the primary impact is on heating, demand impact is characterized for heating and as a penalty (increase in electric consumption).

$$\Delta kW_{Penalty} = \Delta kWh_{Penalty} / EFLH$$

Symbol Table

Electric Energy Savings

$$\Delta kWh_{Penalty} = kBtuh \times (-1/(COP \times 3.412)) \times EFLH$$

Symbol Table

Fossil Fuel Savings

$$\Delta MMBtu = (kBtuh / 1000) \times EFLH \times (1/AFUE)$$

Where:

$\Delta kW_{Penalty}$	=	Total average winter coincident peak kW increase (deemed assumption for prescriptive)
$\Delta kWh_{Penalty}$	=	Gross customer electric energy penalty (deemed assumption for prescriptive)
ΔMMBtu	=	MMBtu savings for each fuel type (deemed assumption for prescriptive)
AFUE	=	Annual Fuel Utilization Efficiency; the efficiency of the fossil fuel heating system (see tables 1 and 2 for more detail)
COP	=	Coefficient of Performance for the installed air to water heat pump (see table 3 for more detail)
EFLH	=	Equivalent full load heating hours = 1,626 hours (residential)[7] = 1,062 hours (commercial)[8]
kBtuh	=	Average rated heating capacity (see table 5 for more detail as the average rated heating capacity varies over the different bin sizes)[9] = 39.14 kBtu/h

Table 4 - Boiler Fuel Type Distribution[5]

Replacement Scenario	Fuel Type	Residential	Commercial
RET	Fuel Oil	56.2%	46.8%
	Propane	39.6%	53.2%
	Wood	4.2%	0.0%
MOP	Fuel Oil	14.8%	0.0%
	Propane	74.1%	75.9%
	Wood	11.1%	24.1%

Table 5 - Deemed Energy Savings Summary[6]

	Rated Heating	Rated Heating	Average Rated					

Sector	Capacity Bins (Tons)	Capacity Range (Tons)	Heating Capacity (kBtu/h)	ΔkWh	ΔkW	ΔMMBtu_Oil	ΔMMBtu_LP	ΔMMBtu_Wood
Residential	2	<= 2.5	25.83	-4,472	-2.75	17.7	26.1	4.5
	3	> 2.5 and <=3.5	33.16	-5,692	-3.50	22.8	33.5	5.7
	4	> 3.5	47.55	-7,799	-4.80	32.6	48.1	8.2
Commercial	2	<= 2.5	25.83	-2,921	-2.75	11.6	32.8	6.8
	3	> 2.5 and <=3.5	33.16	-3,718	-3.50	14.8	42.1	8.7
	4	> 3.5	47.55	-5,094	-4.80	21.3	60.3	12.4

Load Shapes

17a Commercial Space heat
5b Residential Space heat

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
17	Commercial Space heat	Active	38.7 %	61.2 %	0.0 %	0.1 %	57.0 %	0.3 %
5	Residential Space heat	Active	42.9 %	57.1 %	0.0 %	0.0 %	25.0 %	0.0 %

Net Savings Factors

Measures

SHFDAWHP	Air to water heat pump - Fuel-fired Baseline

Tracks [Base Track]

6013PRES [is base track]	Pres Equip Rpl
6036RETR [is base track]	Res Retrofit

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Pres Equip Rpl	6013PRES	SHFDAWHP	0.00	0.00
Res Retrofit	6036RETR	SHFDAWHP	0.00	0.00
Pres Equip Rpl	6013PRES	SHFDAWHP	1.00	1.00
Res Retrofit	6036RETR	SHFDAWHP	0.90	1.00

Lifetimes

The expected measure life is assumed to be 18 years.[10]

Measure Cost

The incremental cost is based on the rated heating capacity and replacement scenario, as detailed in table 6 below.

For market opportunity replacement scenarios, the incremental cost is based on an average of equipment list prices supplied by local distributors plus an additional $1,336[11], which is the estimated cost of low temperature hydronic emitters. If an air to water heat pump is retrofitted on an existing high temperature hydronic fossil fuel system, additional emitters are required in order to meet the design load of the building. The added costs of the emitters is assumed in both the market opportunity and the retrofit scenario. It is included in the market opportunity costs because the baseline assumption is a code compliant high temperature fossil fuel hydronic heating system and the low temperature emitters represent an added cost to facilitate the low temperature requirements of the air to water heat pump.

For retrofit replacement scenarios, the incremental cost assumes an additional installation cost of $1,315[12].

Table 6 - Incremental Costs

Rated Heating Capacity Bins (Tons)	Retrofit Incremental Costs	Market Opportunity Incremental Costs	Overall Incremental Costs[6]
2	$6,404	$5,089	$5,746
3	$8,248	$6,934	$7,591
4	$10,199	$8,884	$9,542

Footnotes

[1] Based on the average findings from the, “Vermont Single-Family Existing Homes Onsite Report, Draft”, NMR Group, Inc., December 2017 (page 44). As the efficiency of wood boilers was not detailed in the report, the value is based on professional judgement.

[2] “Vermont Residential New Construction Baseline Study Analysis of On-Site Audits”, NMR Group, Inc., May 12, 2017 (pages 49-50). The efficiency of

natural gas and propane boilers was combined and not included separately in the report. In order to incorporate the propane fuel type into the analysis, opted to use the combined efficiency values for observed natural gas and propane boilers. As the efficiency of wood boilers was not detailed in the report, the value is based on professional judgement.

[3] Mean observed efficiency for boilers for existing commercial buildings, as sourced from; "2016 Vermont Business Sector Market Characterization and Assessment Study", Cadmus, April 2017 (page 65). The efficiency of natural gas and propane boilers was combined and not included separately in the report. In order to incorporate the propane fuel type into the analysis, VEIC opted to use the combined efficiency values for observed natural gas and propane boilers. As the efficiency of wood boilers was not detailed in the report, the value is based on professional judgement.

[4] Minimum efficiency requirements for gas- and oil-fired boilers <300,000 Btu/h, as sourced from the 2015 VT Commercial Building Energy Standards (CBES). As the efficiency of wood boilers is not governed in code compliance, the value is based on professional judgement.

[5] As the program delivery method for this measure is midstream, the intention is the fuel type of the boiler being off-set will be unknown, and this necissitates a fuel type distribution of boilers being impacted by this measure. The MMBtu energy savings are thus split across the different fuel types based on their saturation in the state of Vermont and is dependant on the building stock and sector. Sites utilizing natural gas fuel are excluded from participating in this measure and are removed from consideration in this characterization. The derivation for the fuel type distribution and the accompanying sources can be viewed in detail in the "Air to Water Heat Pump Analysis_v9.xlsx"

[6] Due to the implementation of this measure through a midstream delivery mechanism, the actual replacement scenario (retrofit vs. market opportunity) will be unknown. As a result, the energy savings and incremental costs for the two replacement options were aggregated based on an assumption that 50% of installs will be retrofits.

[7] Residential EFLH is estimated from an 8,760 equivalent full load hours analysis. The analysis assumes the heating system provides heating below 57.5°F, except in summer months May to August, and estimates savings based on incremental efficiency down to the lower heating limit of 0°F. The analysis assumes the heat pump provides heating based on its rated capacity up to the estimated load.

[8] The commercial EFLH is sourced from the New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs, version 4, January 2017 (New York TRM). Hours are based on an average between the city of Massena and Albany; with it being an average between old and new building types and weighted by small commercial buildings.

[9] The equipment capacity is sourced as a weighted average of available equipment from local manufacturers, rated at varying outdoor air temperatures and supply water temperatures, and binned across Burlington, VT weather data down to an outdoor air temperature of 0°F at specified load conditions.

[10] The measure life is assumed to be similar to the measure life for an air source heat pump. While boilers and other hydronic heating systems will typically have measure lives exceeding 20 years, as a conservative estimate, the measure life for an air source heat pump was sourced from "Measure Life Report, Residential and Commercial/Industrial Lighting and HVAC Measures", GDS Associates, June 2007.

[11] "Optimizing Hydronic System Performance in Residential Applications", NREL, October 2013 (page 8). The cost of low temperature hydronic emitters represents a straight average of the three efficiency scenarios incremental costs' that were modeled in the report.

[12] The installation cost is sourced from estimates of two local manufacturers who compared the installation of air to water heat pumps to that of; (1) multi-head mini-split heat pumps, and (2) low temperature condensing boilers. As a result, the estimated installation cost for these two measures was sourced from NEEP Incremental Cost Studies ($893 for a boiler and $1,736 for a multi-head mini-split heat pump) and averaged accordingly.

Brushless Permanent Magnet (BLPM) Circulator Pump

Measure Number:	VII-C-3 c
Portfolio:	89
Status:	Inactive
Effective Date:	2015/1/1
End Date:	2018/12/31
Program:	Existing Homes
End Use:	HVAC

Update Summary

Referenced Documents

- 2016 RES BLPM CIRC PUMP Analysis_HDD60
- 98 PIP High Perf Circ Pump_2015 Final

Description

This measure characterization is for installing fractional horsepower circulator pumps with brushless permanent magnet pump (BLPM) motors. Typical applications include baseboard and radiant floor heating systems that utilize a primary/secondary loop system in single-family residences. Circulator pumps that use BLPMs are more efficient because they lack brushes that add friction to the motor, as well as the ability to modulate their speed to match the load. This is possible because the drive senses the difference between the magnetic field of the rotating rotor and the rotating magnetic field of the windings in the motor stator. As the system flow demand changes (zones open or close), the drive senses the torque difference at the impeller via the change in the magnetic field difference and adjusts its speed by altering the frequency to the motor. BLPMs are especially efficient in no-load/low-load applications.

The Efficiency Vermont High Performance Circulator Pump (HPCP) Program is a pilot program to promote the installation of efficient brushless permanent magnet motor (BLPM) circulator pumps with integrated variable speed controls in Vermont homes and businesses. The program is offered to HVAC distributors who sell/ship equipment in Vermont, and provides upstream financial incentives at the wholesale level for qualifying circulator pumps sold for installation in a commercial facility or residential home in Vermont.

Baseline Efficiencies

The baseline equipment is a circulator pump using a low-efficiency shaded pole motor. It is assumed that this pump is installed on the primary loop of a multi-loop system, and is running constantly when outside temperatures are 55°F or lower during the winter heating season (October – April).

Efficient Equipment

The efficient equipment is a circulator pump with brushless permanent magnet motor.

Algorithms

Electric Demand Savings

ΔkW	= ΔkWh / HOURS

Symbol Table

Electric Energy Savings

ΔkWh	= HOURS x ((Watts$_{Base}$ – Watts$_{EE}$) / 1000) x ISR

Symbol Table

Fossil Fuel Savings
Midlife Adjustment
Water Savings

Where:

ΔkW	=	Gross customer connected load kW savings for the measure (kW) = 0.06598 kW
ΔkWh	=	Gross customer annual kWh savings for the measure (kWh) = 87.5 kWh
HOURS	=	1,325[1]

ISR = In Service Rate, or the percentage of units rebated that actually get used

= 90%[2]

$Watts_{Base}$ = Baseline connected kW

= 87.7 Watts[3]

$Watts_{EE}$ = Energy efficient connected kW

= 14.4 Watts[3]

Load Shapes

5b Residential Space heat

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
5	Residential Space heat	Active	42.9 %	57.1 %	0.0 %	0.0 %	25.0 %	0.0 %

Net Savings Factors

Measures

MTRCIRCZ	Efficient Circulator Pump Motor

Tracks [Base Track]

6032EPEP [is base track]	Efficient Products - Residential

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Efficient Products - Residential	6032EPEP	MTRCIRCZ	1.00	1.00

Lifetimes

20 years – typical circulator pumps using shaded pole motors are expected to last around 15 years; circulator pump motors with ECMs typically operate at lower RPMs, thus producing less heat and extending the life of the motor.

Measure Cost

The estimated incremental cost for this measure is $100.

O&M Cost Adjustments

There are no O&M cost adjustments associated with this measure.

Persistence

The persistence factor is assumed to be 1.

Footnotes

[1] Efficiency Vermont performed a metering study to better understand run hours of high performance circulator pumps. Analysis can be found in 2016 RES BLPM CIRC PUMP Analysis_HDD60.xlsx.

[2] In-Service Rate Study performed by Efficiency Vermont and Technical Advisory Group (TAG) 2015 agreement found the annual ISR to be 90%.

[3] Efficiency Vermont performed a metering study to better understand watt draw. Analysis can be found in 2016 RES BLPM CIRC PUMP Analysis_HDD60.xlsx.

Residential Efficient Space Heating System

Measure Number: VII-C-7 b
Portfolio: EVT TRM Portfolio 2017-07
Status: Active
Effective Date: 2018/1/1
End Date: [None]
Program: Existing Homes
End Use: HVAC

Update Summary

This is a reliability update that includes an updated VGS Data Regression Analysis for EFLH calculations, which aligns with the Advanced Thermostat measure. Average capacity of heating systems was updated to show actual data from VGS Data Regression. As costs are directly linked to capacity and efficiencies, the costs were also updated with this reliability update.

Referenced Documents

- DOE_Small_appendix_e
- NEEP Residential Boilers 2011_08_18
- NEEP Residential Furnace Analysis 2011_08_19
- NEEP Incremental Cost Study Report 2011
- VT SF Existing Homes Onsite Report_final 021513
- vgs-usage-regression-work-06272017-xlsx
- residential-heating_and_cooling-systems-initiative_cee
- EVT_RES Efficient Space Heating Savings_Analysis_July 2017
- evt-estimated-heating-full-load-hours-July-2017
- furnaces_nopr_tsd_2015-02-13
- technical-support-document---residential-boilers_doe
- CostsFurnacesBoilersNEW

Description

This measure applies to the installation of primary oil- or propane-fired boiler or furnace heating systems in residential existing homes applications. Fossil fuel savings are realized due to the higher AFUE of the qualifying equipment. All systems must be installed per the VT Residential Building Energy Standards and all boiler installations must incorporate high performance Circulator Pumps (electric savings for this will be claimed based on existing measure characterizations).

This measure will provide a standard incentive through two channels. First through the existing Home Performance with ENERGY STAR (HPwES) program where this measure will continue to be treated as an Early Replacement since Efficiency Vermont's involvement results in replacements that would not likely have occurred otherwise. The savings from HPwES projects are generated through modeling software (not characterized here), and a mid life baseline shift will be incorporated to account for the hypothetical future baseline replacement at the AFUE level presented below, consistent with the Market Opportunity measure. The second channel is through the Energy Efficiency Network (EEN) whereby member HVAC contractors and fuel dealers will be able to offer an identical incentive for their customers to upsell to the higher efficiency levels. For measures installed this way (outside of Home Performance with ENERGY STAR) a market opportunity baseline will be used.

Baseline Efficiencies

Baseline equipment is a new standard efficiency oil- or propane-fired furnace or boiler with an AFUE provided below.

Efficient Equipment

The installed oil or propane furnace or boiler must have an AFUE greater than those shown below.

Unit Type	$AFUE_{Base}$	$AFUE_{Eff}$
Oil Boiler	85%	87%
LP Boiler	86.7%	95%
Oil Furnace	82.6%	87%
LP Furnace	88%	95%

Algorithms

Electric Demand Savings

N/A

Electric Energy Savings

The electrical energy and demand savings associated with high performance Circulator Pump is provided in a standalone characterization.

Fossil Fuel Savings

ΔMMBTU	$= (FLH \times (Capacity / 1{,}000{,}000) \times (1/AFUE_{Base} – 1 /AFUE_{Eff})$

Refer to the table of deemed savings in Measure Savings Summary section below.

Symbol Table

Midlife Adjustment

For the Early Replacement measure the initial baseline is the existing unit efficiency. A mid life baseline adjustment will be incorporated to account for the hypothetical new baseline replacement at the same AFUEbase level provided below. It is assumed that this baseline shift will occur after a third of the measure life – so after 5 years for furnaces and 8.3 years for boilers.

Where:

ΔMMBTU = Gross customer annual MMBtu fuel savings for the measure.

1,000,000 = Conversion from Btuh to MMBtu/hour.

$AFUE_{Base}$ = Efficiency of baseline equipment in AFUE[1].
Refer to table above in Efficient Equipment section.

$AFUE_{Eff}$ = Efficiency of new equipment in AFUE[2].
Refer to table above in Efficient Equipment section.

Capacity = capacity of equipment to be installed (Btuh)[3]

Unit Type	Capacity (Btuh)
Boiler	97,754
Furnace	78,379

FLH = Estimated average full load heating hours.
= 714 for boilers and 922 for furnaces[4]

Load Shapes

N/A

Net Savings Factors

Measures

SHRBFOIL	Replace boiler, fuel oil
SHRBPROP	Replace boiler, propane
SHRFFOIL	Replace furnace, fuel oil
SHRFPROP	Replace furnace, propane

Tracks [Base Track]

6036RETR [is base track]	Res Retrofit

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
Res Retrofit	6036RETR	SHRBFOIL	1.00	1.00
Res Retrofit	6036RETR	SHRBPROP	1.00	1.00
Res Retrofit	6036RETR	SHRFFOIL	1.00	1.00
Res Retrofit	6036RETR	SHRFPROP	1.00	1.00

Lifetimes

Equipment Type	Measure Lifetime[5]
Furnaces	15
Boilers	25

Measure Cost

The incremental costs of more efficient equipment are detailed below[6]:

Unit Type	Baseline cost	Efficient Cost	Incremental Cost
Oil Boiler	$4,316	$4,642	$326
LP Boiler	$4,894	$6,843	$1,948
Oil Furnace	$2,906	$3,574	$668
LP Furnace	$2,594	$3,341	$747

Costs for the early replacement measure include the baseline avoided cost in the midlife adjustment.

O&M Cost Adjustments

O&M cost estimates for baseline and efficient boilers and furnaces are provided below[7]

Unit Type	Baseline Annual O&M Cost	Efficient Annual O&M Cost
Boilers	$89.55	$92.55
Furnaces	$39.55	$40.06

Persistence

The persistence factor is assumed to be one.

Measure Savings Summary

Unit Type	ΔMMBTU
Oil Boiler	1.9
LP Boiler	7.0
Oil Furnace	4.4
LP Furnace	6.1

Footnotes

[1] Based on the average findings from p60, NMR Group Inc "Vermont Single-Family Existing Homes Onsite Report. Final 2/15/2013". Note these are significantly above the Federal Minimum Standard but represent an estimate of what people are purchasing without Efficiency Vermont intervention.

[2] The efficiency criteria were developed based on consideration of availability of product, incremental cost etc and with input from EEN representatives.

[3] Average of capacities of boilers and furnaces found in VGS Usage Regression work. See Cells AP11 and AP12 in vgs-usage-regression-work-06272017-xlsx.xlsx. Assumed average values used for prescriptive savings purposes

[4] Estimated by following a methodology outlined in the Uniform Methods Project using natural gas billing data provided by Vermont Gas Systems (VGS) for homes that participated in Efficiency Vermont's Residential New Construction (RNC) program. Since capacity has not been collected through the Home Performance with ENERGY STAR program it was not possible to perform the analysis with a more appropriate data set for this program. The RNC data was limited to only those homes with annual gas consumption greater than 25 kBtu/SF in an attempt to remove the high performance/ low load homes in RNC. See "EVT estimated heating full load hours.doc" for greater explanation and Cells AM11 and AM12 on EFL Filtered tab 'vgs-usage-regression-work-06272017' for analysis.

[5] Page 8, Residential Heating and Cooling Systems Initiative Description, CEE, May 28, 2015. residential-heating_and_cooling-systems-initiative_cee.pdf.

[6] Costs are derived based upon the NEEP Incremental Cost Study (http://neep.org/emv-forum/forum-products-and-guidelines/#Incremental) and also cross checking with the DOE Technical Appliance Standards Technical Support Document "Appendix E. Engineering Analysis Cost and Efficiency Tables". See 'CostsFurnacesBoilersNEW.xls'.

[7] O&M Costs originate from 2015 DOE Technical Support documents for residential furnaces and boilers: furnaces_nopr_tsd_2015-02-13.pdf and technical-support-document---residential-boilers_doe.pdf. Please find the trend anlaysis on the O&M Costs sheet of the analysis document: CostsFurnacesBoilersNEW.xlsx.

Pellet & Wood Stoves

Measure Number: VIII-C-13 a
Portfolio: EVT TRM Portfolio 2018-08
Status: Active
Effective Date: 2018/1/1
End Date: [None]
Program: Existing Homes
End Use: HVAC

Update Summary

New measure

Referenced Documents

- VT SF Existing Homes Onsite Report_final 021513
- VGS Usage Regression Work_04182017
- NMR_Survey Analysis of Owners in Existing Homes in Vermont_Dec 2016
- VT Res Baseline SFNC Onsite report - DRAFT 051217
- EIA_Updated Bldg Sector Appliance & Equipment Costs_June 2018
- VT Dept of Forests_Residential Fuel Assessment Report_Mar 2016
- VT Dept of Public Service_November 2016 Fuel Price Report
- EVT_Pellet Wood Stoves_Analysis_Aug 2018 _v2

Description

This is a retrofit measure that applies to the installation by an approved contractor of a new wood or pellet stove in a new or existing residential building. It is assumed that the home will use a second space heating system in addition to the stove and that the stove will offset a portion of the existing heating system's fuel consumption.

Stoves must be installed according to manufacturer's recommendations and meet the following minimum efficiency and emissions requirements:

- 70% efficiency
- ≤2.0 of particulate matter less than 2.5 microns ($PM_{2.5}$)[1]

This measure provides separate assumptions for replacement of existing wood stoves that are still operational. Existing stoves must be non-EPA certified or if EPA-certified, manufactured prior to 1998 and not meeting 2020 New Source Performance Standards.

Baseline Efficiencies

For customers who are not replacing an existing wood stove, the baseline is a blend of LP, oil, wood, pellet, and electric heating systems, based on the percentage of each system installed as a primary heating source in existing Vermont homes for retrofits or in new Vermont homes for new construction (NC).

For customers replacing an existing wood stove, the baseline is an existing wood stove that is still operational. Existing stoves must be non-EPA certified or if EPA-certified, manufactured prior to 1998 and not meeting 2020 New Source Performance Standards.

Efficient Equipment

The new equipment must be a new wood or pellet stove installed according to manufacturer's recommendations and meeting minimum efficiency and emissions requirements.

In 2018 and forward, in TEPF-funded programs, EVT will not count the increased wood fuel use associated with biomass fuel switches from fossil fuels. Therefore, this measure does not apply a biomass heating penalty, except when the baseline is wood or pellets.

Algorithms

Electric Demand Savings

New pellet or wood stove, not replacing existing wood stove: ΔkW $= \Delta kWh_{Net} / FLH_{Central}$

Replacing existing wood stove with new pellet stove: ΔkW $= \Delta kWh_{Net} / FLH_{Stove}$

Symbol Table

Electric Energy Savings

The electric and demand savings from the use of a new pellet or wood stove in place of an existing electric central heating system and the electric and demand penalties from the use of a new pellet stove are described below.

For customers that are not replacing existing wood stoves:

Measure Code	Item Code	Building Type	New Stove Type	ΔkWh_{Save}	$\Delta kWh_{Penalty}$	ΔkWh_{Net}	ΔkW
SHFHWOOD	RES-STOVE-W-EH1		Wood	190.5	N/A	190.5	0.24423

SHFHWODP	RES-STOVE-P-EH1	Existing	Pellet	187.5	-175.0	12.5	0.01603
SHFHWOOD	RES-STOVE-W-NC1	NC	Wood	486.6	N/A	486.6	0.74290
SHFHWODP	RES-STOVE-P-NC1		Pellet	479.1	-175.0	304.1	0.46427

For customers that are replacing existing wood stoves:

Measure Code	Item Code	Building Type	New Stove Type	ΔkWh_{Save}	$\Delta kWh_{Penalty}$	ΔkWh_{Net}	ΔkW
SHRHWOOD	RES-STOVE-W-ER2	Existing	Wood	N/A	0.0	0.0	0.00000
SHRHWODP	RES-STOVE-P-ER2		Pellet	N/A	-175.0	-175.0	0.12500

New pellet stove, not replacing existing wood stove: ΔkWh_{Net} $= \Delta kWh_{Save} - \Delta kWh_{Penalty}$

New wood stove, not replacing existing wood stove: ΔkWh_{Net} $= \Delta kWh_{Save}$

Replacing existing wood stove with new stove: ΔkWh_{Net} $= \Delta kWh_{Penalty}$

ΔkWh_{Save} $= FLH_{Central} \times (Capacity / 1,000,000) / n_{Base, Electric} \times 293.071 \times \%stove \times \%Elec$

$\Delta kWh_{Penalty}$ $= FLH_{Stove} \times (Watts_{Stove} / 1,000)$

Symbol Table

Fossil Fuel Savings

The fuel savings from the use of a new pellet or wood stove in place of an LP, oil, wood, or pellet heating system or an existing wood stove, the fuel penalties from the use of a new pellet or wood stove, and net savings for each baseline fuel type are described below.

For customers that are not replacing existing wood stoves:

Measure Code	Item Code	Building Type	New Stove Type	Baseline System Fuel Type	$\Delta MMBtu_{Save}$ (by fuel type)	$\Delta MMBtu_{Penalty}$	$\Delta MMBtu_{Net}$ (total savings after applying penalty)
SHFHWOOD	RES-STOVE-W-EH1	Existing	Wood	LP	10.659	N/A	10.659
				Oil	40.192	N/A	40.192
				Wood	4.071	3.528	0.543
				Pellet	0.000	N/A	0.000
SHFHWODP	RES-STOVE-P-EH1		Pellet	LP	10.495	N/A	10.495
				Oil	39.574	N/A	39.574
				Wood	4.008	N/A	4.008
				Pellet	0.000	3.428	-3.428
SHFHWOOD	RES-STOVE-W-NC1	NC	Wood	LP	21.264	N/A	21.264
				Oil	2.357	N/A	2.357
				Wood	11.595	15.690	-4.095
				Pellet	4.042	N/A	4.042
SHFHWODP	RES-STOVE-P-NC1		Pellet	LP	20.937	N/A	20.937
				Oil	2.321	N/A	2.321
				Wood	11.416	N/A	11.416
				Pellet	3.979	15.246	-11.267

For customers that are not replacing existing wood stoves with new pellet or wood stoves, MMBtu savings and penalties are provided below. A mid-life adjustment should be applied after 10 years, which is assumed to be the remaining life of the existing wood stove. At that point, it is assumed that the customer would install a new, baseline stove.

Measure Code	Item Code	Building Type	New Stove Fuel Type	$\Delta MMBtu_{Save}$ for the remaining life of the existing stove (first 10 years)	$\Delta MMBtu_{Save}$ for the remaining measure life (next 8 years)	$\Delta MMBtu_{Penalty}$	$\Delta MMBtu_{Net}$ for the remaining life of the existing stove (first 10 years)	$\Delta MMBtu_{Net}$ for the remaining measure life (next 8 years)	Mid-Life Adjustment (applied after first 10 years)

SHRHWOOD	RES-STOVE-W-ER2	Existing	Wood	89.273	63.592	61.896	27.377	1.696	6.2%
SHRHWODP	RES-STOVE-P-ER2		Pellet			60.142	29.131	3.450	11.8%

$\Delta MMBtu_{Net}$ $= \Delta MMBtu_{Save} - \Delta MMBtu_{Penalty}$

LP savings, not replacing existing wood stove: $\Delta MMBtu_{Save, LP} = FLH_{Central} \times (Capacity / 1{,}000{,}000) / \eta_{Base, LP} \times \%stove \times \%Fuel_{LP}$

Oil savings, not replacing existing wood stove: $\Delta MMBtu_{Save, Oil} = FLH_{Central} \times (Capacity / 1{,}000{,}000) / \eta_{Base, Oil} \times \%stove \times \%Fuel_{Oil}$

Wood savings, not replacing existing wood stove: $\Delta MMBtu_{Save, Wood} = FLH_{Central} \times (Capacity / 1{,}000{,}000) / \eta_{Base, Wood} \times \%stove \times \%Fuel_{Wood}$

Pellet savings, not replacing existing wood stove: $\Delta MMBtu_{Save, Pellet} = FLH_{Central} \times (Capacity / 1{,}000{,}000) / \eta_{Base, Pellet} \times \%stove \times \%Fuel_{Pellet}$

Penalty, not replacing existing wood stove: $\Delta MMBtu_{Penalty} = FLH_{Central} \times (Capacity / 1{,}000{,}000) / \eta_{New\ Stove} \times \%stove \times (\%Fuel_{Wood} + \%Fuel_{Pellet})$

Savings, replacing existing wood stove (first 10 years): $\Delta MMBtu_{Save} = FLH_{Central} \times (Capacity / 1{,}000{,}000\ ) / \eta_{Existing\ Stove} \times \%stove$

Savings, replacing existing wood stove (next 8 years): $\Delta MMBtu_{Save} = FLH_{Central} \times (Capacity / 1{,}000{,}000\ ) / \eta_{Baseline\ Stove} \times \%stove$

Penalty, replacing existing wood stove: $\Delta MMBtu_{Penalty} = FLH_{Central} \times (Capacity / 1{,}000{,}000) / \eta_{New\ Stove} \times \%stove$

Where:

%Elec = Percentage of homes assumed to have electric heating systems; see table below

Building Type	%Elec
Existing[4]	1.4%
New Construction[5]	15.4%

$\%Fuel_{LP}$ = Percentage of homes assumed to use LP heating systems; see table within $\%Fuel_{Wood}$ definition for for each building type and fuel type.

$\%Fuel_{Oil}$ = Percentage of homes assumed to use oil heating systems; see table within $\%Fuel_{Wood}$ definition.

$\%Fuel_{Pellet}$ = Percentage of homes assumed to use pellet heating systems; see table within $\%Fuel_{Wood}$ definition.

$\%Fuel_{Wood}$ = Percentage of homes assumed to use wood heating systems; see table below for %Fuel for each building type and fuel type.

Building Type	Fuel Type	%Fuel
Existing[4]	LP	20.0%
	Oil	72.9%
	Wood	5.7%
	Pellet	0.0%
New Construction[5]	LP	50.0%
	Oil	5.1%
	Wood	21.8%
	Pellet	7.7%

%stove = Percentage of annual total heating load provided by stove

%stove

Wood[6]	Pellet[7]
65%	64%

ΔkW = Gross customer annual connected load kW savings for the measure

ΔkWh_{Net} = Gross customer annual kWh savings for the measure after subtracting the kWh penalty from use of a pellet stove

$\Delta kWh_{Penalty}$ = Gross annual kWh penalty from the use of a pellet stove

ΔkWh_{Save} = Gross customer annual kWh savings for the measure

$\Delta MMBtu_{Net}$ = Gross customer annual MMBtu fuel savings for the measure after subtracting the MMBtu penalty

$\Delta MMBtu_{Penalty}$ = Gross customer annual MMBtu fuel penalty from use of cordwood or pellets, based on the percentage of wood and pellet space heating in homes

$\Delta MMBtu_{Save, LP}$ = Gross customer annual MMBtu fuel savings for the measure (LP baseline)

$\Delta MMBtu_{Save, Oil}$ = Gross customer annual MMBtu fuel savings for the measure (oil baseline)

$\Delta MMBtu_{Save, Pellet}$ = Gross customer annual MMBtu fuel savings for the measure (pellet baseline)

$\Delta MMBtu_{Save, Wood}$ = Gross customer annual MMBtu fuel savings for the measure (wood baseline)

$\Delta MMBtu_{Save}$ = Gross customer annual MMBtu fuel savings for the measure (calculated separately for each baseline fuel type)

1,000,000 = Factor to convert Btu/hr to MMBtu/hr

293.071 = Factor to convert MMBtu to kWh

Capacity = Average capacity of primary space heating systems installed in Vermont homes

Building Type	Capacity[2]
Existing	91,562
NC	93,695

$FLH_{Central}$ = Average full load heating hours of central space heating systems in Vermont homes

Building Type	FLH[2]
Existing	780
NC	655

FLH_{Stove} = Average full load heating hours of stoves

= 1,400[3]

$\eta_{Base, Pellet}$ = Efficiency of baseline pellet heating system; see table within $\eta_{Base, Wood}$ definition

$\eta_{Base, Electric}$ = Efficiency of baseline electric heating system; see table within $\eta_{Base, Wood}$ definition

$\eta_{Base, LP}$ = Efficiency of baseline LP heating system; see table within $\eta_{Base, Wood}$ definition

$\eta_{Base, Oil}$ = Efficiency of baseline oil heating system; see table within $\eta_{Base, Wood}$ definition

$\eta_{Base, Wood}$ = Efficiency of baseline wood heating system; see table below for ηBase values based on building type and fuel type

Building Type	Fuel Type	η_{Base}
Existing[9]	Electric	1.00
	LP	0.871
	Oil	0.842
	Wood	0.65
New Construction[10]	Electric	3.7
	LP	0.938
	Oil	0.863
	Wood	0.75
	Pellet	0.76

$\eta_{Baseline Stove}$ = Efficiency of baseline stove that it is assumed a customer would install after the remaining life of the existing wood stove (10 years)

= 0.73[11]

$\eta_{Existing Stove}$ = Efficiency of existing wood stove that is being replaced

= 0.52[12]

$\eta_{New\ Stove}$ = Efficiency of new stove[13]

New Stove Type	$\eta_{New\ Stove}$
Wood	0.75
Pellet	0.76

$Watts_{Stove}$ = Energy consumption (watts) of new stove

New Stove Type	$Watts_{Stove}$
Wood	0
Pellet	125[8]

Load Shapes

5b Residential Space heat

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
5	Residential Space heat	Active	42.9 %	57.1 %	0.0 %	0.0 %	25.0 %	0.0 %

Net Savings Factors

Measures

SHFHWOOD	Fuel switch, space heater, wood
SHRHWOOD	Replace space heater, wood
SHFHWODP	Fuel switch, space heater, wood pellet
SHRHWODP	Replace space heater, wood pellet

Tracks [Base Track]

6032UPST [6032EPEP]	Upstream - Residential

Lifetimes

The expected measure life is assumed to be 18 years.[14]

For early replacement of wood stoves, the existing wood stove is assumed to have a remaining life of 10 years.

Measure Cost

The measure cost is the total installed cost (equipment and labor) for a wood or pellet stove:[15]

New Stove Type	Stove Cost	Installation Cost	Other Costs*	Total Installed Cost
Cordwood	$2,475	$383	$469	$3,319
Pellet	$3,366	$340	$694	$4,400

*Costs not included in "stove cost" or "installation cost," such as miscellaneous parts or recycling fees.

For early replacement of wood stoves, the assumed deferred cost (after 10 years) of replacing existing equipment with a new baseline wood stove meeting New Source Performance Standards is assumed to be $2,655.[16]

O&M Cost Adjustments

For customers that are not replacing existing wood stoves:

Building Type	New Stove Type	Annual Baseline O&M Cost[17]	Annual O&M Costs with New Stove[18]	Annual O&M Cost Adjustment (Penalty)
Existing	Wood	$106	$229	-$123
	Pellet		$298	-$192
NC	Wood	$125	$236	-$111
	Pellet		$305	-$180

For customers that are replacing existing wood stoves with new pellet or wood stoves:

Annual Baseline O&M Cost[19]	**New Stove Type**	**Annual O&M Costs with New Stove**[19]	**Annual O&M Cost Adjustment (Penalty)**
$192	Wood	$192	$0
	Pellet	$260	-$68

Footnotes

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[1] Requirement from EPA New Source Performance Standards for year 2020

[2] FLH and capacity values estimated by following a methodology outlined in the Uniform Methods Project using natural gas billing data provided by Vermont Gas Systems (VGS) for homes that participated in Efficiency Vermont's Residential New Construction (RNC) program. Since capacity has not been collected through the Home Performance with ENERGY STAR program it was not possible to perform the analysis with a more appropriate data set for this program. For Existing Homes, the RNC data was limited to only those homes with annual gas consumption greater than 25kBtu/sq ft in an attempt to remove the high performance/ low load homes in RNC. See 'VGS Usage Regression Work_04182017.xls' for analysis. For existing homes, final FLH and capacity values were calculated using boiler and furnace weightings from NMR Group, "VT SF Existing Homes Onsite Report," 2013, page 58, Table 5-4. For new construction, weightings are from NMR Group, "Vermont Residential New Construction Baseline Study Analysis of On-Site Audits (Draft Report)," May 12, 2017, page 47, Table 47.

[3] FLH for stoves estimated by the Biomass Energy Resource Center

[4] Percentage of heating system fuel types in existing Vermont homes from NMR Group, "Survey Analysis of Owners of Existing Homes in Vermont (Draft)" December 5, 2016: page 29, Table 38 (Efficiency Vermont data). Natural gas, coal, and solar were excluded. The report states that "all nine respondents who use electricity as their primary heating fuel reported that they have electric resistance baseboard rather than an electric heat pump." Percentage of wood from boilers and furnaces (versus stoves) estimated as 4% based on data received by Efficiency Vermont on 08/21/2017 from the upcoming NMR Vermont Residential Market Assessment.

[5] Percentage of heating system fuel types in new residential buildings in Vermont based on data from NMR Group, "Vermont Residential New Construction Baseline Study Analysis of On-Site Audits (Draft Report)," May 12, 2017: page 45, Table 46 (Efficiency Vermont data). Natural gas excluded.

[6] %stove for wood stoves is calculating using: the percentage of primary (53%) versus supplemental (47%) cordwood users in Vermont and the annual number of cords burned by primary (4.8) versus supplemental (2.1) cordwood users from Vermont Department of Forests, Parks, and Recreation, "Vermont Residential Fuel Assessment for the 2014-2015 Heating Season," March 2016, page 6; an average annual heat load of 80.832 MMBtu for Vermont homes (700 gallons/oil per year based on 2016 VT Tier III TAG agreement/84.2% oil heating system efficiency in existing VT homes); 68% stove efficiency based on data received by Efficiency Vermont on 08/21/2017 from the upcoming NMR Vermont Residential Market Assessment; and 22.0 MMBtu/cord heat content from the November 2016 VT Fuel Price Report. %stove is calculated as ((53% (4.8 cords/yr * 22.0 MMBtu/cord * 68% / 80.832)) + (47% (2.1 cords/yr * 22.0 MMBtu/cord * 68% / 80.832)). See %stove tab in file EVT_Pellet Wood Stove_Analysis_Aug 2018_v2.xlsx for calculation.

[7] %stove for pellet stoves is calculating using: the percentage of primary (70%) versus supplemental (30%) pellet users in Vermont and the annual tons of pelelts burned by primary (4.4) versus supplemental (3.3) pellet users from Vermont Department of Forests, Parks, and Recreation, "Vermont Residential Fuel Assessment for the 2014-2015 Heating Season," March 2016, pages 7-8; an average annual heat load of 80.832 MMBtu for Vermont homes (700 gallons/oil per year based on 2016 VT Tier III TAG agreement/84.2% oil heating system efficiency in existing VT homes); 77% stove efficiency based on data received by Efficiency Vermont on 08/21/2017 from the upcoming NMR Vermont Residential Market Assessment; and 16.4 MMBtu/ton heat content from the November 2016 VT Fuel Price Report. %stove is calculated as ((70% (4.4 tons/yr * 16.4 MMBtu/ton * 77% / 80.832)) + (30% (3.3 tons/yr * 16.4 MMBtu/ton * 77% / 80.832)). See %stove tab in file EVT_Pellet Wood Stove_Analysis_Aug 2018_v2.xlsx for calculation.

[8] Typical pellet stove energy consumption at normal burn rates estimated by the Biomass Energy Resource Center. Includes ignitor, feed auger, and blowers.

[9] Efficiencies of LP and oil heating systems in existing homes are a weighted average based on the percentage of boilers and furnaces used as single major heating system in existing Vermont homes from NMR Group, "Vermont Single-Family Existing Homes Onsite Report," February 15, 2013: pages 58-61, Tables 5-4, 5-8 and 5-9. Stoves in existing homes with electric space heating are assumed to replace electric resistance systems with an efficiency of 1.00. Efficiency of wood heating systems is based on professional judgment. See nBase & nExisting tab within file EVT_Pellet Wood Stove_Analysis_Aug 2018_v2.xlsx for calculations.

[10] Efficiencies of electric, LP, and oil heating systems in new homes are based on data from NMR Group, "Vermont Residential New Construction Baseline Study Analysis of On-Site Audits (Draft Report),"May 12, 2017. Boiler, furnace, and heat pump weightings are from page 47, Table 47, and equipment efficiencies are from pages 49-50, Tables 50-52. Oil boilers, combined appliances, wood stoves and furnaces, pellet stoves, natural gas units, and heat pumps were removed from boiler and furnace weighting calculations. Values for Efficiency Vermont used. nBase (LP) is a weighted average based on the percentage of LP boilers and furnaces installed in new Vermont homes. Nbase (oil) is the efficiency of oil boilers. Efficiencies of wood and pellet heating systems are the efficiencies of new stoves meeting 2020 NSPS and 70% efficiency requirements on EPA's list of certified wood heaters as of May 2018. See nBase & nExisting tab within file EVT_Pellet Wood Stove_Analysis_Aug 2018_v2.xlsx for calculations.

[11] Efficiency of baseline stove is the average efficiency of stoves meeting 2020 NSPS requirements from EPA's list of certified stoves as of May 2018.

[12] Efficiency of existing wood stove being replaced is an estimate provided by the Biomass Energy Resource Center based on review of information provided by the Alliance for Green Heat.

[13] Average efficiency of new stoves meeting 2020 NSPS and 70% efficiency requirements on EPA list of certified wood heaters as of May 2018

[14] Average of lifetimes provided for residential cordwood and pellet stoves in U.S. EIA, "Updated Buildings Sector Appliance and Equipment Costs and

Efficiencies," June 2018.

[15] Average costs from the Renewable Energy Resource Center from December 2016 through April 2017. See Measure Cost tab within file EVT_Pellet Wood Stove Analysis_Aug 2018_v2.xlsx.

[16] Based on estimate that a baseline stove meeting NSPS standards costs 80% of an average stove meeting program requirements.

[17] Baseline O&M costs for existing homes are based on the percentage of each heating system fuel type in existing Vermont homes from NMR Group, "Survey Analysis of Owners of Existing Homes in Vermont (Draft)" December 5, 2016: page 29, Table 38 (Efficiency Vermont data). LP and oil systems are weighted based on the percentage of boilers and furnaces in Vermont homes from NMR Group, "VT SF Existing Homes Onsite Report," 2013, page 58, Table 5-4. Baseline O&M costs for new construction are based on the percentage of each heating system in new Vermont homes from NMR Group, "Vermont Residential New Construction Baseline Study Analysis of On-Site Audits (Draft Report)," Prepared by NMR Group for Vermont DPS, May 12, 2017: page 47, Table 47 (Efficiency Vermont data). Combined appliances and natural gas and systems excluded. Costs for LP and oil boilers and furnaces, wood stoves, pellet stoves, and heat pumps are from U.S. EIA, "Updated Buildings Sector Appliance and Equipment Costs and Efficiencies," November 2016. According to the report, O&M costs for electric resistance heating systems are negligible; $10 was assumed in these calculations. Costs for cordwood boilers and furnaces are assumed to the same as costs for pellet boilers. See "O&M Costs" tab in file EVT_Pellet & Wood Stoves_Analysis_Aug 2018_v2.xlsx for calculation.

[18] O&M costs with new wood stove include the percentage of existing heat system O&M costs that are not displaced by the new stove (Baseline O&M Cost * (1 - %stove)), plus the full O&M costs associated with the new stove. New stove O&M costs are from U.S. EIA, "Updated Buildings Sector Appliance and Equipment Costs and Efficiencies," November 2016. See O&M Costs tab within file EVT_Pellet Wood Stoves_Analysis_Aug 2018_v2.xlsx for calculation.

[19] Baseline and new O&M costs for customers replacing existing wood stoves are the full O&M costs for wood or pellet stoves from U.S. EIA, "Updated Buildings Sector Appliance and Equipment Costs and Efficiencies," November 2016.

Home Energy Kit

Measure Number: **VII-J-2 b**
Portfolio: EVT TRM Portfolio 2018-05
Status: Active
Effective Date: 2018/1/1
End Date: [None]
Program: Existing Homes
End Use: Multiple

Update Summary

LED lamp assumptions have been revised to align with a revision made to the ENERGY STAR Integrated Screw Based SSL (LED) Lamps measure under EVT TRM Portfolio 2017-12, effective 1/1/2018: change to mid-life adjustment and O&M calculations to delay EISA baseline assumption for year 2020 to 2021.

The O&M calculations have been revised to reflect a 15 year LED lifetime. Part of the O&M calculations in the previous version of the measure were erroneously assuming a 25-year lifetime.

The shower restriction valve savings have been revised to match an update to the Thermostatically Initiated Shower Restriction Valve measure under EVT TRM Portfolio 2018-03, efective 1/1/2018. The baseline for that measure was revised from a 1.5 gpm showerhead to a federal standard 2.5 gpm showerhead.

Referenced Documents

- RLW FCM Demand Impacts Standards Development
- DEER2014-EUL-table-update_2014-02-05.xlsx
- NMR Group, Inc., "Northeast Residential Lighting Hours-of-Use Study," prepared for CT Energy Efficiency Board, Cape Light Compact, Massachusetts Energy Efficiency Advisory Council, National Grid MA, National Grid RI, NYSERDA, Northeast Utilities, May 5, 2
- UMPChapter21-residential-lighting-evaluation-protocol
- Lockeed Martin Energy Solutions nyserda_powerstrip_report
- Cadmus_Ameren Missouri EP Impact & Process Evaluation_May 2016
- Navigant_energySMART Energy Savings Kits_Apr 2016
- Schultdt_Energy Related Water Fixture Measurements_2008
- CalPlug_Tier2_APS_Evaluation
- Cadmus_Process Evaluation Report PPL Electric Program Year 5_Nov 2014
- EVT_Home Energy Kit_Analysis_May 2018

Description

This measure applies to Home Energy Kits provided to customers who visit Home Ownership Centers and express interest in these kits during their visit. The measure is characterized for 2 types of Kits. Kit A & B.

Kits consist of a combination of the following products: 9W, CEE Tier 1 omnidirectional LED bulbs, Tier 1 advanced power strips, faucet aerators with a flow rate of 1.5 gallons per minute (gpm), low-flow showerheads with a flow rate of 1.5 gpm, and thermostatically-initiated shower restriction valves. See savings tables for product mix of Kit A & B.

Baseline Efficiencies

For CEE Tier 1 omnidirectional LED bulbs, the baseline is a mix of CFL bulbs and EISA-compliant incandescent and halogen bulbs, based on the percentage of each bulb type installed in homes. In 2021, the baseline will become the EISA backstop requirement of 45 lumens per watt efficacy.

For Tier 1 advanced power strips, the baseline is a standard power strip that does not control any of the connected loads.

For low-flow faucet aerators, the baseline is a standard faucet aerator with a flow rate of 2.2 gpm. Savings assumptions include a 0.83 throttling factor[1] for baseline faucets to account for the fact that faucets are not always operated at full flow, reducing the flow rate to 1.83 gpm.

For low-flow showerheads, the baseline is a standard showerhead with a flow rate of 2.5 gpm.

For thermostatically-initiated shower restriction valves, the baseline is no restriction valve in place.

Efficient Equipment

The efficient equipment is a Home Energy Kit consisting of a combination of the following products: 9W, CEE Tier 1 omnidirectional LED bulbs, Tier 1 advanced power strips, faucet aerators with a flow rate of 1.5 gallons per minute (gpm), low-flow showerheads with a flow rate of 1.5 gpm, and thermostatically-initiated shower restriction valves.   Savings assumptions for faucet aerators include a 0.95 throttling factor[1] for new faucets to account for the fact that faucets are not always operated at full flow, reducing the flow rate to 0.95 gpm.

Baseline Adjustment

To account for EISA requirements, the future savings for LED lamps included in Home Energy Kits should be reduced to account for the higher baselines in 2021. The following table shows the calculated adjustments for a 60-watt equivalent, 9-watt LED bulb.[2]

LED	**Bulb Wattages Assumed in Calculation**		**2021 Savings Adjustment**

(Watts)	Base 2016-2020 (Watts)	Base 2021 (Watts)	Factor
9.0	29.8	17.3	40.0%

Algorithms

Electric Demand Savings

ΔkW_{LED} $= SaveDemand_{LED} \times ISR_{LED} \times Num_{LED}$

ΔkW_{APS} $= \Delta kWh_{APS} / HOURS_{APS}$

$\Delta kW_{Aerator}$ $= \Delta kWh_{Aerator} / HOURS_{DHW\_Conserve}$

$\Delta kW_{Showerhead}$ $= \Delta kWh_{Showerhead} / HOURS_{DHW\_Conserve}$

$\Delta kW_{Shower\ Valve}$ $= \Delta kWh_{Shower\ Valve} / HOURS_{DHW\_Conserve}$

Symbol Table

Electric Energy Savings

Electric Energy and Demand Savings

Home Energy Kit A				
Product	**2016-2020**		**2021**	
	ΔkW	**ΔkWh**	**ΔkW**	**ΔkWh**
CEE Tier 1, Omnidirectional Bulbs (total for 2 bulbs)	0.03747	36.9	0.01498	14.8
Tier 1 Advanced Power Strip	0.00416	33.5	0.00416	33.5
Faucet Aerator (total for 2 aerators)	0.00256	8.8	0.00256	8.8
Low-Flow Showerhead	0.01524	52.2	0.01524	52.2
Thermostatically-Initiated Shower Restriction Valve	0.00345	11.8	0.00345	11.8
Home Energy Kit A Total	**0.06288**	**143.2**	**0.04039**	**121.1**

Home Energy Kit B				
Product	**2016-2020**		**2021**	
	ΔkW	**ΔkWh**	**ΔkW**	**ΔkWh**
CEE Tier 1, Omnidirectional Bulbs (total for 2 bulbs)	0.03747	36.9	0.01498	14.8
Faucet Aerator (total for 2 aerators)	0.00256	8.8	0.00256	8.8
Low-Flow Showerhead	0.01524	52.2	0.01524	52.2
Home Energy Kit B Total	**0.05527**	**97.9**	**0.3278**	**75.8**

ΔkWh_{LED} $= SaveElec_{LED} \times ISR_{LED} \times Num_{LED}$

ΔkWh_{APS} $= SaveElec_{APS} \times ISR_{APS}$

$\Delta kWh_{Aerator}$ $= SaveElec_{Aerator} \times ISR_{Aerator} \times Num_{Aerator} \times \%Electric\_DHW$

$\Delta kWh_{Showerhead}$ $= SaveElec_{Showerhead} \times ISR_{Showerhead} \times \%Electric\_DHW$

$\Delta kWh_{Shower\ Valve}$ $= SaveElec_{Shower\ Valve} \times ISR_{Shower\ Valve} \times \%Electric\_DHW$

Symbol Table

Fossil Fuel Savings

Fossil Fuel Savings

Home Energy Kit A				
Product	**ΔMMBtu (fuel oil)**	**ΔMMBtu (natural**	**ΔMMBtu (propane)**	**ΔMMBtu (total)**

		gas)		
Faucet Aerator (total for 2 aerators)	0.030	0.039	0.041	0.110
Low-Flow Showerhead	0.179	0.233	0.242	0.654
Thermostatically-Initiated Shower Restriction Valve	0.041	0.053	0.055	0.148
Home Energy Kit A Total				**0.912**

Home Energy Kit B				
Product	**ΔMMBtu (fuel oil)**	**ΔMMBtu (natural gas)**	**ΔMMBtu (propane)**	**ΔMMBtu (total)**
Faucet Aerator (total for 2 aerators)	0.030	0.039	0.041	0.110
Low-Flow Showerhead	0.179	0.233	0.242	0.654
Home Energy Kit B Total				**0.764**

$\Delta MMBtu_{Aerator}$ $= SaveFuel_{Aerator} \times ISR_{Aerator} \times Num_{Aerator}\ x\ \%Fuel\_DHW$

$\Delta MMBtu_{Showerhead}$ $= SaveFuel_{Showerhead} \times ISR_{Showerhead}\ x\ \%Fuel\_DHW$

$\Delta MMBtu_{Shower\ Valve}$ $= SaveFuel_{Shower\ Valve} \times ISR_{Shower\ Valve}\ x\ \%Fuel\_DHW$

Symbol Table

Water Savings

Water Savings

Home Energy Kit A	
Product	**ΔCCF**
Faucet Aerator (total for 2 aerators)	0.52
Low-Flow Showerhead	2.29
Thermostatically-Initiated Shower Restriction Valve	0.52
Home Energy Kit A Total	**3.33**

Home Energy Kit B	
Product	**ΔCCF**
Faucet Aerator (total for 2 aerators)	0.52
Low-Flow Showerhead	2.29
Home Energy Kit A Total	**2.81**

$\Delta CCF_{Aerator}$ $= SaveWater_{Aerator} \times ISR_{Aerator}\ x\ Num_{Aerator}$

$\Delta CCF_{Showerhead}$ $= SaveWater_{Showerhead} \times ISR_{Showerhead}$

$\Delta CCF_{Shower\ Valve}$ $= SaveWater_{Shower\ Valve} \times ISR_{Shower\ Valve}$

Where:

%Electric_DHW = Proportion of water heating supplied by electricity

= 25%[7]

%Fuel_DHW = Proportion of water heating supplied by fuel oil, natural gas, or propane[7]

Fuel Oil	Natural Gas	Propane
20%	26%	27%

$\Delta CCF_{Aerator}$ = Gross customer annual water savings for low-flow faucet aerators (see table "Water Savings")

$\Delta CCF_{Shower\ Valve}$ = Gross customer annual water savings for thermostatically initiated shower restriction valves (see table "Water Savings")

$\Delta CCF_{Showerhead}$ = Gross customer annual water savings for low-flow showerheads (see table "Water Savings")

$\Delta kW_{Aerator}$ = Gross customer annual kW savings for low-flow faucet aerators (see table "Electric Energy and Demand Savings")

ΔkW_{APS} = Gross customer annual kW savings for Tier 1 advanced power strips (see table "Electric Energy and Demand Savings")

ΔkW_{LED} = Gross customer annual kW savings for CEE Tier 1 omnidirectional LED bulbs (see table "Electric Energy and Demand Savings")

$\Delta kW_{Shower\ Valve}$ = Gross customer annual kW savings for thermostatically initiated shower restriction valves (see table "Electric Energy and Demand Savings")

$\Delta kW_{Showerhead}$ = Gross customer annual kW savings for low-flow showerheads (see table "Electric Energy and Demand Savings")

$\Delta kWh_{Aerator}$ = Gross customer annual kWh savings for low-flow faucet aerators (see table "Electric Energy and Demand Savings")

ΔkWh_{APS} = Gross customer annual kWh savings for Tier 1 advanced power strips (see table "Electric Energy and Demand Savings")

ΔkWh_{LED} = Gross customer annual kWh savings for CEE Tier 1 omnidirectional LED bulbs (see table "Electric Energy and Demand Savings")

$\Delta kWh_{Shower\ Valve}$ = Gross customer annual kWh savings for thermostatically initiated shower restriction valves (see table "Electric Energy and Demand Savings")

$\Delta kWh_{Showerhead}$ = Gross customer annual kWh savings for low-flow showerheads (see table "Electric Energy and Demand Savings")

$\Delta MMBtu_{Aerator}$ = Gross customer annual MMBtu savings for low-flow faucet aerators (see table "Fossil Fuel Savings")

$\Delta MMBtu_{Shower\ Valve}$ = Gross customer annual MMBtu savings for shower restriction valves (see table "Fossil Fuel Savings")

$\Delta MMBtu_{Showerhead}$ = Gross customer annual MMBtu savings for low-flow showerheads (see table "Fossil Fuel Savings")

$HOURS_{DHW\_Conserve}$ = Annual full load hours for DHW conservation measures

= 3,427.1 hours[3]

$HOURS_{APS}$ = Average advanced power strip hours of use per year in efficient (controlled off) mode

= 8,048 hours[4]

$ISR_{Aerator}$ = In service rate or the percentage of units rebated that actually get used, for faucet aerators

= 0.57[8]

ISR_{APS} = In service rate or the percentage of units rebated that actually get used, for Tier 1 advanced power strips

= 0.63[9]

ISR_{LED} = 0.90[5]

$ISR_{Shower\ Valve}$ = 0.45[10]

$ISR_{Showerhead}$ = In service rate or the percentage of units rebated that actually get used, for showerheads

= 0.56[11]

$Num_{Aerator}$ = Number of faucet aerators included in one Home Energy Kit

= 2

Num_{LED} = Number of LED bulbs included in one Home Energy Kit

= 2

$SaveDemand_{LED}$ = Annual electric demand savings (kW) for a CEE Tier 1 omnidirectional LED bulb

= 0.02085 kW for years 2018-2020[6]

= 0.00833 kW for year 2021

$SaveElec_{Aerator}$ = Annual electric energy savings (kWh) for a low-flow faucet aerator

= 30.8 kWh[12]

$SaveElec_{APS}$ = Annual electric energy savings (kWh) for a Tier 1 advanced power strip

= 53.1 kWh[13]

$SaveElec_{LED}$ = Annual electric energy savings (kWh) for a CEE Tier 1 omnidirectional LED bulb

= 20.5 kWh for years 2018-2020[6]

= 8.2 kWh for year 2021

$SaveElec_{Shower\ Valve}$ = Annual electric energy savings (kWh) for a shower restriction valve

= 105.2 kWh[14]

$SaveElec_{Showerhead}$ = Annual electric energy savings (kWh) for a low-flow showerhead

= 373.1 kWh[15]

$SaveFuel_{Aerator}$ = Annual fossil fuel savings (MMBtu) for a low-flow faucet aerator

= 0.132 MMBtu[12]

$SaveFuel_{Shower\ Valve}$ = Annual fossil fuel savings (MMBtu) for a shower restriction valve

= 0.451 MMBtu[14]

$SaveFuel_{Showerhead}$ = Annual fossil fuel savings (MMBtu) for a low-flow showerhead

= 1.600 MMBtu[15]

$SaveWater_{Showerhead}$ = Annual water savings (CCF) for a low-flow showerhead

= 4.09 CCF[15]

$SaveWater_{Aerator}$ = Annual water savings (CCF) for a low-flow faucet aerator

= 0.46 CCF[12]

$SaveWater_{Shower\ Valve}$ = Annual water savings (CCF) for a shower restriction valve

= 1.15 CCF[14]

Load Shapes

For aerators, showerheads, and shower valves:

For DHW systems not on Utility Controlled DHW program (Default):
Loadshape #8, Residential DHW Conservation

Loadshapes #8 is based on Itron 8760 hourly load data.

For controlled power strips, see file Loadshape_smart_revB.xls.

For LED bulbs:

Residential: Loadshape #1: Residential Indoor Lighting

1a Residential Indoor Lighting
8a Residential DHW conserve
96a Standby Losses - Entertainment Center

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
1	Residential Indoor Lighting	Active	36.9 %	35.0 %	13.0 %	15.1 %	29.8 %	8.2 %
8	Residential DHW conserve	Active	48.7 %	29.1 %	14.3 %	7.9 %	40.1 %	20.3 %
96	Standby Losses - Entertainment Center	Active	32.0 %	35.0 %	16.0 %	17.0 %	72.5 %	90.0 %

Net Savings Factors

Measures

ZZZEEKIT	Home Energy Efficiency Kit

Tracks [Base Track]

6034LISF [is base track]	LISF Retrofit
6036RETR [is base track]	Res Retrofit
6032LIEP [6032EPEP]	Efficient Products - Low Income

Lifetimes

See the table below for the measure lifetime for each product included in a Home Energy Kit.

Product	Lifetime (years)
CEE Tier 1 Omnidirectional LED Bulbs	15[16]
Tier 1 Advanced Power Strips	5[17]
Low-Flow Faucet Aerators	10[18]
Low-Flow Showerheads	10[18]
Thermostatically-Initiated Shower Restriction Valves	10[19]

Measure Cost

The measure cost is the actual cost of the kit incurred by the program.

O&M Cost Adjustments

To account for the shift in baseline due to EISA standards, the levelized baseline replacement cost over the lifetime of the LED lamps is calculated based on the following assumptions.[20]

Assumptions	Base 2016-2020	Base 2021
Replacement Cost	$1.94	$2.50
Component Life (hours)	5,001	10,000

The calculation results in the following equivalent annual baseline replacement cost.

Annual baseline O&M assumption for bulbs installed in		
2018	2019	2020
$0.38	$0.32	$0.27

Footnotes

[1] Schultdt, Marc, and Debra Tachibana, "Energy Related Water Fixture Measurements: Securing the Baseline for Northwest Single Family Homes. 2008 ACEEE Summer Study on Energy Efficiency in Buildings," 2008, page 1-265.

[2] For additional details on the baseline adjustment calculation see reference file EVT_Home Energy Kit_Analysis_May 2018.xlsx.

[3] Full load hours from Loadshape #8a (Residential DHW Conserve) and #54a (Controlled DHW Conservation).

[4] Derived from CalPlug Tier 2 APS Evaluation Study Retrieved from: http://embertec.com/assets/pdf/CalPlug_Tier2_APS_Evaluation.pdf.

Advanced power strips are assumed to be plugged in at all times. Annual hours when the equipment is turned off are 7,340. The equipment is estimated to be in standby mode 1.94 hours/day or 708 hours/year. Savings are achieved during periods when equipment is off or in standby mode. Thus, the hours of operation used to determine demand savings are 7,340 + 708 = 8,048. No savings are achieved during the remaining 712 hours per year when equipment is in use.

[5] Lifetime ISR for LED bulbs based on methodology from Chapter 21: Residential Lighting Evaluation Protocol of the Uniform Methods Project. Using a 1st Year ISR of 70% (1st year ISR value for both CFL and LED bulbs in efficiency kits is 59% in the Illinois Technical Reference Manual for Energy Efficiency, Version 6.0 ("Free bulbs provided without request, with little or no education. Based on 'Impact and Process Evaluation of 2013 (PY6) Ameren Illinois Company Residential CFL Distribution Program', Report Table 11 and Appendix B."). Efficiency Vermont assumes the ISR for free LED bulbs is higher than for free CFL bulbs.) and a discount rate of 3.00% based on the Vermont societal cost test, the lifetime ISR after three years is 90%. See file EVT_Home Energy Kit_Analysis_May 2018.xlsx for calculaton details.

[6] Annual kW and kWh values for LED bulbs assume an LED bulb wattage of 9W, which is the actual wattage of LED lamps provided in Home Energy Kits. Baseline wattage values are based on a 60W-equivalent bulb. The baseline wattage for 2018-2020 assumes 44% of existing bulbs in homes are 60 lu/watt CFLs and 56% are EISA-compliant incandescents/halogens. Bulb saturation is based on data for Vermont existing homes received by Efficiency Vermont on 08/21/2017 from the upcoming NMR Vermont Residential Market Assessment. LED bulbs were removed from the analysis since EVT assumes that LED bulbs from kits will not replaced LED bulbs already installed in homes. Base wattage for 2021 is the EISA backstop

requirement of 45 lu/watt. Annual kWh calculations also assume 986 annual hours of use based on NMR, "Northeast Residential Lighting Hours-of-Use Study", 5/5/2014. Page 34, Table 3-1. See file EVT_Home Energy Kit_Analysis_May 2018.xlsx for calculaton details.

[7] DHW fuel percentages based on data received by Efficiency Vermont on 08/21/2017 from the upcoming NMR Vermont Residential Market Assessment.

[8] Average of kits aerator in service rate (average of 61.5%) from Navigant, "energySMART Energy Savings Kits, GPY 4 Evaluation Report (FINAL)," April 29, 2016, p. 20, and kits aerator in service rate for single family homes (52%) from Cadmus, "Ameren Missouri Efficient Products Impact and Process Evaluation: PY 2015," May 13, 2016, p. 23.

[9] Advanced power strip ISR is average of ISRs from Cadmus, "Process Evaluation Report, PPL Electric EE&C Plan, Program Year Five," November 13, 2014, p. 147.

[10] In the absence of evaluation studies supporting an ISR for free shower restriction valves, EVT began with the ISR assumption for low-flow showerheads (56%) and reduced the ISR to 45% for shower restriction valves since customers are likely to be less familiar with these products.

[11] Average of showerhead in service rate for kits including one showerhead (65%) from Navigant, "energySMART Energy Savings Kits, GPY 4 Evaluation Report (FINAL)," April 29, 2016, p. 20, and kits showerhead in service rate for single family homes (47%) from Cadmus, "Ameren Missouri Efficient Products Impact and Process Evaluation: PY 2015," May 13, 2016, p. 23.

[12] Annual kWh, MMBtu, and CCF values for faucet aerators are Direct Install values for 1.5 gpm aerators from the "Low Flow Faucet Aerator" measure (effective 01/01/2017) under the Existing Homes program within the EVT TRM.

[13] Annual kWh savings value for Tier 1 advanced power strips is from the "Controlled Power Strip" measure (effective 01/01/2018) under the Efficient Products program within the EVT TRM. Values for entertainment centers (75.1 kWh) and home offices (31 kWh) were averaged.

[14] Annual kWh, MMBtu, and CCF values for shower restriction valves are from the "Thermostatically Initiated Shower Restriction Valve" measure (effective 01/01/2018) under the Efficient Products program within the EVT TRM.

[15] Annual kWh, MMBtu, and CCF values for low-flow showerheads are from the "Low Flow Showerhead" measure (effective 01/01/2017) under the Existing Homes program within the EVT TRM.

[16] The lifetime for LED bulbs is the actual rated life of the product provided in kits (25,000 hours) divided by annual hours of use (986 hours). All lighting lifetimes are capped at 15 years (although their rated life/hours is higher).

[17] 10-year estimate: Lockheed Martin, Inc., Energy Solutions, Advanced Power Strip Research Report Final Report, Prepared for the New York State Energy Research and Development Authority (NYSERDA), 2011. As persistence has not been studied for this measure, 5 years is being used as a conservative estimate.

[18] Measure lifetime from California DEER. See file DEER2014-EUL-table-update_2014-02-05.xlsx.

[19] California DEER Ex Ante Database

[20] For additional details on O&M cost adjustments see reference file EVT_Home Energy Kit_Analysis_May 2018.xlsx.

DIY Insulation and Airsealing

Measure Number: VII-K-1 b
Portfolio: EVT TRM Portfolio 2018-02
Status: Active
Effective Date: 2018/1/1
End Date: [None]
Program: Existing Homes
End Use: Shell

Update Summary

This is a new Efficiency Vermont offering and version one of the characterization.

Referenced Documents

- NEST VEIC Data Share 9Jun2017
- VT SF Existing Homes Onsite Report - DRAFT 122117
- DIY Support Workbook FINAL
- DIY_Manual_Final
- EfficiencyVermont_DIY_Rebate_Checklist

Description

This characterization is in support of Efficiency Vermont's Existing Homes DIY (Do-It-Yourself) Program. As such, the savings estimates described by this characterization may be lower than those resulting from work performed by a skilled professional. Participants can elect to weatherize (airseal and insulate) either their flat, open attic OR their basement/crawlspace rim joists and walls. Best practices and program requirements are fully outlined in the DIY Quality Standard Manual. With the exception of selecting treatment area, site-specific heating systems and fuel types, savings for this measure are fully deemed values. Although this characerization is broken out by airsealing and insulation savings components, the final savings claim for the appropriate treatment area will be the sum of these two components. This is a retrofit measure, savings energy by increasing the thermal resistance of building assemblies and reducing air infiltration that would subsequently need to be heated by the heating system(s).

QA sampling is a critical component of a DIY measure savings claim, and therefore thoughtful sample design should be performed to ensure acceptable confidence levels are achieved, especially in instances when it is not possible to inspect every measure or project.

As a means to ensure DIY projects maintain appropriate quality standards and do not create health and safety concerns, Efficiency Vermont will perform QAs on the first ten projects that submit rebate forms as part of this program. This enables Efficiency Vermont to evaluate the types of projects being submitted and what, if any, issues arise from the outset and immediately course correct. The remainder of the QAs will be completed throughout the market testing – 50% of DIY projects will be QA'd up to 100 projects. QA will be completed by an Efficiency Vermont Energy Consultant (EC) who specializes in weatherization projects. The expectation that a project may be subject to a QA visit will be made clear from the outset and will be included in the customer sign-off box. When a project is selected, The QA visit will, at a minimum;

1. Review self-install checklist and verify compliance.
2. Review Rebate application form and verify values.
3. Examine all accessible areas of work for insulation installation quality, thickness/R-value and air sealing.
4. Conduct a blower door test.
5. Use an infrared camera to inspect the quality of the air sealing work.
6. Conduct CAZ testing in accordance with BPI standards.
7. Identify any moisture concerns or other health and safety issues.
8. Identify additional opportunities for saving energy and providing clear guidance on taking next steps.

The primary intent of the visit will be to identify and address any health and safety concerns, assess the quality of DIY installations, provide additional educational support, and identify other efficiency opportunities that are present.

Based on conversations with Energy Trust of Oregon, it is anticipated that QA failures are based on missed air sealing, poor technique, or insufficient insulation. In these cases, the QA Manager will discuss best practices with the homeowner, instruct them on how to address the area, and explain the energy implications of poor quality installation. Full combustion safety testing will be conducted to educate the homeowner and show impact. The QA Manager will provide the homeowner with a report that outlines the areas that need to be improved and the appropriate educational pieces that correlate. The homeowner will be required to sign the document attesting that they will fix the issue and take responsibility. If the market testing reveals that further education about proper installation is needed Efficiency Vermont is prepared to create additional support opportunities for homeowners.

Health and safety failures will be treated with much higher importance and care. If during the visit the QA Manager identifies a CAZ failure such as a gas leak, they will immediately explain the concern to the homeowner and give them a list of next steps. When appropriate, they will provide a list of certified professionals who can address the issue. Depending on the nature of the issue, Efficiency Vermont may provide follow up visits or require documentation from the homeowner to ensure the issue has been appropriately addressed.

At the conclusion of the visit, the QA Manager will provide a leave-behind sheet that details possible next steps in achieving a more energy efficient home as an effort to promote re-engagement. After the visit the QA Manager will leave a tear-off copy of the QA Checklist with the homeowner to highlight the homeowner's successes or identify areas of improvement, including a summary of any discussed solutions for addressing quality issues. In the case of a health and safety failure requiring immediate attention, the report will be sent as soon as possible and will include actionable next steps to mitigate the concern. The homeowner will sign stating that they understand that it is their responsibility to take the corrective action outlined in the document.

Note, if a project receives a drastic 'fail' (ie: R values are significantly lower than the quality standards manual) in the QA process and, savings claims will be adjusted appropriately.

Once homeowner completes the project, QA is complete and they receive their rebate check, Efficiency Vermont will send a survey as follow up. There will be continued engagement letters sent out at the 12 week and 1 year marks. This enables Efficiency Vermont to continue to support the homeowner and ensure they are aware of other efficiency opportunities to them.

Additional program materials are linked in the Referenced Documents section and include the program rebate form and quality standards manual.

Baseline Efficiencies

Baseline existing home attic and basement conditions are in large part defined by the information and data published in the Vermont Single-Family Existing Homes On-Site Report, December 21, 2017. Baseline is therefore loosely defined as the typical, single-family existing home attic or basement that falls within EVT market territory. Descriptions, footnotes and references in the remaining characterization content clearly specify and describe the baseline treatment area characteristics.

Efficient Equipment

The efficient condition upgrades the insulation properties of the attic structural assembly to an overall weighted value of R-49 or the basement structural assembly to R-15. Additionally, comprehensive air sealing must have occurred, preferably through the application of polyurethane foam.

Algorithms

Electric Demand Savings

Demand savings are exclusive to the heating season and the winter peak demand period. The total electric savings for each source (e.g., heat pump) resulting from insulating and airsealing are divided by the expected full load heating hours to establish the demand reduction. The loadhshape is subsequently used in conjunction with this value to establish winter peak demand savings.

$$kWh_{source} / EFLH_{eheat}$$

Symbol Table

Energy Savings: Airsealing

$$\%_{Load} \times \beta_{CFM50} \times \tau \times \psi \times SF_n \times HDH_n \times 60 \times c_p \times \rho / (\eta_{source} \times N_{heat} \times \omega)$$

Symbol Table

Energy Savings: Insulation

This characterization limits the savings claim to the primary heating system only, although it is common for homes to have multiple heating sources. Both insulation and airsealing savings components are claimed and savings are limited to space heating savings. The savings calculations must be performed for the primary heating source, i.e., the system that contributes the largest proportion of heating load on a annual basis. An example at the end of this section illustrates how this characterization is used to claim savings.

$$\%_{Load} \times (1/R_{pre} - 1/R_{post}) \times SF_n \times HDH_n \times \psi / (\eta_{source} \times \omega)$$

Where:

$\%_{Load}$ = Portion of annual heating load supplied by the primary heating source.[2]

= 92.0%

β_{CFM50} = Infiltration improvement factor (CFM_{50}/ft^2)[3]

= 0.86878 (CFM_{50}/ft^2)

η_{source} = Operating efficiency of the heating source[4], dependent of fuel and system type:

System/Fuel Type		Efficiency
Boiler	Oil	0.85
	Nat. Gas	0.873
	Propane	0.874
Furnace	Oil	0.814
	Nat. Gas	0.921
	Propane	0.90
Other	Pellet stove	0.70
	Newer EPA woodstove	0.60
	Cataylitic woodstove	0.50
	Non-catalytic woodstove	0.40
	Outdoor wood boiler	0.25
	Open hearth fireplace	0.10
	Gas/Propane stove	0.65

	Heat Pump	2.93
	Electric Resistance	1.00

ω = Conversion factor from Btu to MMBtu or kWh, as appropriate

= 1,000,000 (Btu/MMBtu) or 3,412.14 (Btu/kWh)

ψ = Adjustment factor to bring savings estimates given by this simplified algorithm to evaluation bill anaylsis results.[5]

= 0.76 (dimensionless)

ρ = Density of air at prevalent conditions during the heating season (lb/ft^3)

= 0.0749 (lb/ft^3)

τ = De-rating factor to account for the presumed installation quality differences between a DIY customer and a professional contractor (made necessary because the infiltration improvement factor is based on professionally installed projects)

= 0.75 (dimensionless)[6]

60 = Converts volumitric air flow per minute to hour

= 60 (minutes/hour)

c_p = Specific heat of air at prevalent conditions during the heating season (Btu/lb F)

= 0.24 (Btu/lb F)

$EFLH_{eheat}$ = Effective Full Load Hours for electric heating source (hours)

= 1,354.8 (hours)[1]

HDH_n = Heating Degree Hours[7], dependent on space being treated (F hr):

= 127,691.3 (F hr) for flat, open attic OR 99,194.6 (F hr) for basement/crawlspace rim joists and walls

kWh_{source} = Total electric energy savings from the primary, secondary, or tertiary source for insulation and airsealing improvements, as calculated in the **Energy Savings: Insulation** and **Energy Savings: Airsealing** sections (kWh)

N_{heat} = Conversion factor from volumetric air flow at 50 Pascal pressure to natural conditions[8]

= 20 (dimensionless)

R_{post} = Thermal resistance of the improved (post-treatment) assemblies separating conditioned space to the ambient environment[10], dependent on space being treated (hr F ft^2/Btu):

= 49.0 (hr F ft^2/Btu) for flat, open attic OR 22.4 (hr F ft^2/Btu) for basement/crawlspace rim joists and walls

R_{pre} = Thermal resistance of the existing (pre-treatment) assemblies separating conditioned space to the ambient environment[11], dependent on space being treated (hr F ft^2/Btu):

= 29.0 (hr F ft^2/Btu) for flat, open attic OR 15.2 (hr F ft^2/Btu) for basement/crawlspace rim joists and walls

SF_n = Area of treatment with improved insulation and airsealing properties[9]

= 852.87 (ft^2) for flat, open attic OR 967.59 (ft^2) for basement/crawlspace rim joists and walls

The following table summarizes the savings outcomes for each treatment area, treatment activity, heating system type, and fuel type. To exemplify how savings shall be claimed, let's assume a project has weatherized an open attic. The site has a primary natural gas furnace.

Natural gas savings: savings from insulating are established as 1.164 MMBtu and savings from airsealing are established as 2.909 MMBtu for total natural gas savings of 4.073 MMBtu

Summarized Savings Outcomes

				Flat, Open Attic	Basement/Crawlspace Rim Joists and Walls
System/Fuel Type		Treatment	Savings Units	Primary Heat Souce, 92% heating load	Primary Heat Souce, 92% heating load
Boiler	Oil	Insulation		1.261	1.672
		Airsealing		3.152	2.778
		Total		4.413	4.450
	Nat. Gas	Insulation		1.228	1.628
		Airsealing		3.069	2.705
		Total		4.297	4.333
	Propane	Insulation		1.226	1.626
		Airsealing		3.065	2.702
		Total		4.292	4.328
		Insulation		1.317	1.746

Furnace	Oil	Airsealing	MMBtu	3.291	2.901
		Total		4.608	4.647
	Nat. Gas	Insulation		1.164	1.543
		Airsealing		2.909	2.564
		Total		4.073	4.107
	Propane	Insulation		1.191	1.579
		Airsealing		2.977	2.624
		Total		4.168	4.203
Other	Pellet stove	Insulation		1.531	2.030
		Airsealing		3.827	3.373
		Total		5.359	5.404
	Newer EPA woodstove	Insulation		1.786	2.369
		Airsealing		4.465	3.935
		Total		6.252	6.304
	Cataylitic woodstove	Insulation		2.143	2.842
		Airsealing		5.358	4.723
		Total		7.502	7.565
	Non-catalytic woodstove	Insulation		2.679	3.553
		Airsealing		6.698	5.903
		Total		9.377	9.456
	Outdoor wood boiler	Insulation		4.287	5.685
		Airsealing		10.717	9.445
		Total		15.004	15.130
	Open hearth fireplace	Insulation		10.717	14.212
		Airsealing		26.792	23.613
		Total		37.510	37.825
	Gas/Propane stove	Insulation		1.649	2.186
		Airsealing		4.122	3.633
		Total		5.771	5.819
	Heat Pump	Insulation	kWh (kW)	107.2 (0.07911)	142.1 (0.1049)
		Airsealing		267.9 (0.19776)	236.1 (0.17429)
		Total		375.1 (0.27686)	378.2 (0.27919)
	Electric Resistance	Insulation		314.1 (0.23184)	416.5 (0.30744)
		Airsealing		785.2 (0.57958)	692 (0.51079)
		Total		1099.3 (0.81141)	1108.5 (0.81823)

Load Shapes

5b Residential Space heat

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
5	Residential Space heat	Active	42.9 %	57.1 %	0.0 %	0.0 %	25.0 %	0.0 %

Net Savings Factors

Measures

TSHNAIRS	Insulate and airseal

Tracks [Base Track]

6036RETR [is base track]	Res Retrofit

Lifetimes

Lifetimes for both airsealing and insulating components are 25 years.[12]

Measure Cost

Total measure costs are comprised of the cost of airsealing and insulating the treatment area[13]:

Space	Airsealing Cost	Insulation Cost	Total Cost
Flat, Open Attic	$331.43	$694.40	$1,025.83
Basement/Crawlspace Rim Joists and Walls	$331.43	$657.87	$989.30

Footnotes

[1] $EFLH_{eheat}$ is taken to be the established full load hours for a heat pump under the premise that the majority of any eletric heat sources are likely to be heat pumps. Further, as this value is higher than the default EFLH for the loadshape applicable to this measure, the demand savings err on the conservative side. This value is calculated in an analysis of heat pump metered data. The partial load of each heat pump is summed up through the heating season, and taken as an average across all units metered. See TRM measure Variable Speed Mini-Split Heat Pumps for additional background and reference documents. The analysis can be found on the EFLH Calculator tab in the EVT_CCHP MOP and Retrofit_12_2017.xlsx.

[2] Based on analysis of the U.S. Energy Information Administration's Residential Energy Consumption Survey (RECS) 2009 dataset. Homes from the New England Census Division (CT, MA, ME, NH, RI, VT) were included in the analysis. Due to VEIC data systems limitations, only primary heating source savings are quantified and claimed. Savings for the remaining 8% of annual heating load is forgone in exchange for implementation efficiency. For access to the raw dataset and anlaysis, see the "RECS2009" worksheet in the DIY Support Workbook FINAL.

[3] Derived from dataset of ~4,400 past EVT home performance projects. Projects used blower door testing to establish improvement in airsealing performance. Total airsealed area divided by the change in volumetric flow rate blower door reading established the improvement factor for each project. The median value of the entire dataset was chosen to represent the improvement factor for this characterization to limit the impact of outliers. Complete dataset and analysis can be seen on the "Airsealing Improvement Factor" worksheet in the DIY Support Workbook FINAL.

[4] Boiler and furnace efficiencies are the median values reported by the Vermont Single-Family Existing Homes On-Site Report, December 21, 2017 in Tables 46 and 47. Heat pump efficiency conservatively taken to be the minimum qualifying efficiency requirement for EVT's programs, HSPF = 10.0, converted to COP by dividing by 3.41214. All other efficiency values based on professional judgement.

[5] This adjustment factor mirrors that which is applied to HERO-based HPwES projects. Based on the 2013 program impact evaluation and subsequent outcomes of EM&V/DPS negotiations, the 0.76 adjustment factor is intended to better align the savings estimated by HERO algorithms to those established by evaluation. Since the algorithms used by this characterization closely align with HERO, the same adjustment factor is adopted.

[6] Professional judgement. The preferred approach to airsealing, by use of DOW's Froth-Pak, is expected to allow the DIY market to achieve comprehensive and effective levels of airsealing, however on the whole it is likely that the market won't be able to match the qaulity of a job performed by a professional.

[7] Heating Degree Hours for attic assumes a base temperature of 58 degrees F and uses Climate Normals data for Burlington Internation Airport. A recent Nest study by EVT revealed that a base temperature of 58 degrees is appropriate to capture the heating tendencies of a typical Vermont home. See referenced document "NEST VEIC Data Share 9Jun2017." In an attempt to make a conservative estimate of heating degree hours, it was assumed that only days within a defined heating season would be included in the total, assuming that homeowners would disable or set back heating systems in the off season. The heating season was defined as the time period where temperatures "consistently" fall below 58 degrees. Based on visual inspection of TMY3 data, this period was established as September 19th to May 6th. Heating Degree Hours for basement assumes a blend of conditioned and unconditioned space as reported by the Vermont Single-Family Existing Homes On-Site Report, December 21, 2017. Unconditioned space HDH assumes a base temperature of 48 degrees F based on the premise that unconditioned basements are allowed to swing in temperature, are ground coupled, and are usually cool. See worksheets "Foundation Blend" and "HDH - Climate Normals" in the DIY Support Workbook FINAL for a complete derivation.

[8] A legavy negotiated value carried over from a historic EVT Home Performance With Energy Star program performance evaluation finding intended to bring savings predicted by this algorithm in line with evaluated impacts.

[9] The average area for open attics is derived from a dataset of ~4,400 past EVT home performance projects. See worksheets "Additional Assumptions" and "Airsealing Improvement Factor" for a complete derivation. Basement treatment area (wall area) uses median reported floor areas in the Vermont Single-Family Existing Homes On-Site Report, December 21, 2017 (Table 12) as a basis and assumes completely square areas, eight foot wall heights for full basements and four foot wall heights for crawlspaces. Final value is a weighted, composite number based on foundation type and prevalence in the EVT market territory. For a full derivation, see the worksheet "Foundation Blend" in the DIY Support Workbook FINAL.

[10] Based on program requirements, which align with Vermont RBES. The R-value for basements appears higher than what the program and RBES requires (R-15) due to the fact that the thermal resistance properties of soil have been accounted for in basements that are below grade. The final weighted number is a composite value based on statistics of homes with below, mixed and no basement (crawlspace) that have been sourced from the Vermont Single-Family Existing Homes On-Site Report, December 21, 2017. For a full derivation, see the worksheet "Foundation Blend" in the DIY Support Workbook FINAL.

[11] Baseline R-values sourced from the Vermont Single-Family Existing Homes On-Site Report, December 21, 2017. Median (more conservative) value assumed for attics (Table 24, Page 26) and average values assumed for basements (Table 32, Page 32 & Page 33) due to the fact that median is not specified for above grade basement walls. The final value for basements is a weighted, composite value based on statistics of homes with below, mixed and no basement (crawlspace). Additionally, it accounts for the thermal resistance properties of soil. For a full derivation, see the worksheet "Foundation Blend" in the DIY Support Workbook FINAL.

[12] Consistent with EVT TRM measure "Comprehensive Shell Measure Savings"

[13] Cost of airsealing estimated as the purchase cost of the preferred airsealing solution, DOW's Froth-Pak (or equivalent), which is a quick curing polyurethane foam that provides insulating properties in addition to airsealing. The cost of a Froth-Pak 210, which contains 210 board feet of foam volume and is assumed to reqire the necessary coverage for one attic or one basement, is listed as $331.43 at www.lowes.com.

Cost of attic insulation estimated as the purchase cost of 28 rolls of Owens Corning R-30 unfaced continuous fiberglass insulation, $24.80 each at Home Depot. With coverage of 31.25 ft^2 per roll, 28 would be the nearest whole quantity to cover the average area of attics assumed by this characterization, 852.87 ft^2. Despite needing gains of R-20 to bring the typical vermont home up to program requirements, it is assumed that due to deficiencies in installation techniques for the DIY market, a product rated at R-30 would be necessary to achieve the desired improvement.

Cost of basement treatment area insulation is a weighted, composite number based on insulation types in basements as reported by the Vermont Single-Family Existing Homes On-Site Report, December 21, 2017. Similar to attic insulation, it is assumed that a product with a higher R-value rating than the required improvement in R-value will need to be installed to achieve the desired results. Blended costs includes cost assumptions for Owens

Corning R-13 faced fiberglass insulation continuous roll, 40ft^2 coverage per roll ($15.43 each at Home Depot) and Thermasheath Rmax Thermasheath-3 2 in. x 4 ft. x 8 ft. R-13.1 Polyisocyanurate Rigid Foam Insulation Board ($31.95 each at Home Depot). See worksheets "Additional Assumptions" and "Foundation Blend" in the DIY Support Workbook FINAL for a complete derivation.

Efficient Furnace Fan Motor

Measure Number: VII-C-1 d
Portfolio: 77
Status: Active
Effective Date: 2012/1/1
End Date: [None]
Program: Existing Homes
End Use: Space Heating

Referenced Documents

- Pigg_HomeEnergy_2003
- 2009 - Focus on Energy - ECM Furnace Blower Motor Impact Assessment
- FOE to VT Blower Savings
- Efficient Furnace Air Handlers in Massachusett_evaluationreport

Description

This measure will provide incentives for installing an ENERGY STAR qualified natural gas, or propane and an efficient oil fired furnace with a high efficiency brushless permanent magnet fan motor (BPM, also called ECM, ICM, and other terms), hereafter referred to as “efficient fan motor”. This prescriptive measure will apply when retrofitting an existing unit or installing a new furnace. The incentive offer and savings estimation relate only to the efficiency gains associated with an upgrade to an efficient fan motor. For homes that install an efficient furnace fan and have central A/C, additional kWh savings are estimated due to the efficiency gains from the furnace fan which is used to circulate cooled air.

Estimated Measure Impacts

	Average Annual MWH Savings per unit	Average number of measures per year	Average Annual MWH savings per year
Furnace w/ Efficient Motor for Heating Only	0.642	25	16.05
Furnace w/ Efficient Motor for Heating and Cooling	0.675	25	16.875

Algorithms

Electric Energy Savings

To estimate heating, cooling and shoulder season savings for Vermont, VEIC adapted results from a 2009 Focus on Energy study of BPM blower motor savings in Wisconsin. This study included effects of behavior change based on the efficiency of new motor greatly increasing the amount of people that run the fan continuously. The savings from the Wisconsin study were adjusted to account for different run hour assumptions (average values used) for Illinois. See: Reference Table, below and reference doc “FOE to VT Blower Savings.xlsx”.

$\Delta kWh_{\text{Heating Only}}$ = (Heating + Shoulder ΔkWh savings) = 418 + 145 + 79 = 642

$\Delta kWh_{\text{Heating \& Central A/C}}$ = (Heating + Shoulder + Cooling ΔkWh savings) = 418 + 178 + 79 = 675

Symbol Table

Electric Demand Savings

This measure’s peak savings occur in the heating season. Demand savings are accordingly unrelated to the presence of CAC, and are based upon heating savings and heating operating hours. The heating operating hours are based upon the kWh to max kW (1522) used by the loadshape

ΔkW = (Heating ΔkWh savings) / Hours = 405/1522 = 0.27

Symbol Table

Fossil Fuel Savings

No net increase in fossil fuel consumption occurs due to the comparative increase in average AFUEs of furnace models with efficient furnace fans compared to the lower AFUEs of condensing furnaces without efficient furnace fans. The increased AFUEs fully compensates for the lost waste heat from the inefficient furnace fan motors.[1]

$\Delta MMBtu_{Oil}$ = 0

$\Delta MMBtu_{natgas}$ = 0

$\Delta MMBtu_{propane}$	= 0

Where:

ΔkW	=	gross customer connected load kW savings for the measure
ΔkWh	=	gross annual kWh savings for the measure
ΔMMBtu	=	
Heating ΔkWh savings	=	
Hours	=	Fan Heating Operating Hours

Baseline Efficiencies

A furnace meeting minimum Federal efficiency standards using a low-efficiency permanent split capacitor (PSC) fan motor.

High Efficiency

The installed natural gas or propane furnace must be ENERGY STAR qualified, residential sized, i.e. <=200,000 Btu/hr unit that meets the criteria for electricity consumption by the furnace fan motor[2], a calculation of of annual electricity used relative to total energy use. Version 3.0, effective 2/1/2012 requires this new metric to be less than or equal to 2.0%. Version 4.0, effective 2/1/2013 includes a new metric for case leakage with negligible energy impacts. Qualification criteria for oil fired furnaces are that they must be residential sized as described above and have an AFUE >=85 and an EaE <=600.

Operating Hours

Cooling Only: 375 hours/year[3]

Load Shapes

71a Furnace Fan Heating and Cooling
5b Residential Space heat

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
71	Furnace Fan Heating and Cooling	Active	31.7 %	37.5 %	16.9 %	13.9 %	45.4 %	82.9 %
5	Residential Space heat	Active	42.9 %	57.1 %	0.0 %	0.0 %	25.0 %	0.0 %

Net Savings Factors

Measures

SHEFNMTR	Furnace fan motor

Tracks [Base Track]

6018LINC [is base track]	LIMF NC
6019MFNC [is base track]	MF Mkt NC
6032EPEP [is base track]	Efficient Products - Residential
6036RETR [is base track]	Res Retrofit
6038VESH [is base track]	RNC VESH
5102OLS [5100EPEP]	Retail Efficient Products On-line Store

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
LIMF NC	6018LINC	SHEFNMTR	1.00	1.00
MF Mkt NC	6019MFNC	SHEFNMTR	1.00	1.00
Efficient Products - Residential	6032EPEP	SHEFNMTR	1.00	1.00
Res Retrofit	6036RETR	SHEFNMTR	1.00	1.00
RNC VESH	6038VESH	SHEFNMTR	1.00	1.00

Persistence

The persistence factor is assumed to be one.

Lifetimes

18 years.[4]

Analysis period is the same as the lifetime.

Measure Cost

$97[5]

O&M Cost Adjustments

There are no operation and maintenance cost adjustments for this measure.

Fossil Fuel Description

No net increase in fossil fuel consumption occurs due to the comparative increase in average AFUEs of furnace models with efficient furnace fans compared to the lower AFUEs of condensing furnaces without efficient furnace fans. The increased AFUEs fully compensates for the lost waste heat from the inefficient furnace fan motors.[6]

DMMBtu Oil = 0

DMMBtu Nat Gas = 0

DMMBtu Propane = 0

Reference Tables

Efficient Furnace Fan Savings Estimates by Season and presence of Central A/C

Season	Total Savings (kWh)	
	CAC	No CAC
Heating Season	418	418
Cooling Season	178	145
Shoulder Periods	79	79
Total Savings	675	642
Demand Savings	0.27 kW	

Footnotes

[1] Pigg, 2003, Electricity Use By New Furnaces: A Wisconsin Field Study. Page 45 "Impact of ECM Furnaces on Gas Consumption"

[2] Complete Energy Star version criteria and the current methodology for calculating Furnace fan efficiency metric can be found here: http://www.energystar.gov/index.cfm?c=revisions.furnace_spec.

[3] ARI data indicates 500 full load hours for A/C use in Vermont. VEIC experience in other states suggests that ARI estimates for A/C use tend to be overstated. In an effort to compensate for this overstatement, Efficiency Vermont applied a .75 multiplier to the ARI estimate in determining residential A/C hours of use.

[4] "Energy Savings from Efficient Furnace Fan Air Handlers in Massachusetts" ACEEE Sachs and Smith, 2003.

[5] Adapted from Federal Appliance Standard Life-Cycle and Payback Analysis, Tables 8.2.3 and 8.2.13 in http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/hvac_ch_08_lcc_2011-06-24.pdf

[6] Pigg, 2003, Electricity Use By New Furnaces: A Wisconsin Field Study. Page 45 "Impact of ECM Furnaces on Gas Consumption"

Residential Fan—Quiet, Exhaust-Only Continuous Ventilation

Measure Number: III-E-1 d
Portfolio: EVT TRM Portfolio 2017-06
Status: Active
Effective Date: 2017/1/1
End Date: [None]
Program: Existing Homes
End Use: Ventilation

Update Summary

This is part of EVT TRM reliability, as well as adding a two tier set up to account for efficiency differences between ENERGY STAR and ENERGY STAR Most Efficient residential ventilation bath fans.

Referenced Documents

- ASHRAE 62.2 Section 4.1 Whole House Ventilation
- measure_life_GDS[1]
- Navigant Consulting. (2013, January 16). Incremental Cost Study Phase Two Final Report.
- EVT_ENERGY STAR Ventiltion Fan_Analysis_May 2017

Description

This market opportunity is defined by the need for continuous mechanical ventilation due to reduced air-infiltration from a tighter building shell. In retrofit projects, existing fans may be too loud, or insufficient in other ways, to be operated as required for proper ventilation. This measure assumes a fan capacity of 50 CFM rated at less than 2.0 sones at 0.1 inches of water column static pressure. This measure may be applied to larger capacity, up to 130 CFM, efficient fans with bi-level controls because the savings and incremental costs are very similar. All eligible installations shall be sized to provide the mechanical ventilation rate indicated by ASHRAE 62.2. This measure applies to the Low Income Single Family, Multifamily, Residential New Construction, and Existing Homes programs.

Estimated Measure Impacts

Algorithms

Electric Demand Savings

ΔkW	$= CFM \times (1/Fan_{Efficiency,\ Baseline} - 1/Fan_{Efficiency,\ Efficient})/1000$
ΔkW	$= CFM \times (1/Fan_{Efficiency,\ Baseline} - 1/Fan_{Efficiency,\ Most\ Efficient})/1000$

Symbol Table

Electric Energy Savings

ΔkWh	$= Hours \times \Delta kW$

Where:

ΔkW = Gross customer connected load kW savings per qualified ventilation fan and controls.

ΔkWh = Gross customer annual kWh savings per qualified ventilation fan and controls.

CFM = Nominal Capacity of the exhaust fan, 50 CFM[1]

$Fan_{Efficiency,\ Effcient}$ = Average efficacy for ENERGY STAR fan, 4.84 CFM/Watt[5884]

$Fan_{Efficiency,\ Most\ Efficient}$ = Average efficacy for ENERGY STAR fan, 12.48 CFM/Watt[2]

$Fan_{Efficiency,\ Baseline}$ = Average efficacy for baseline fan, 2.8 CFM/Watt[3]

Hours = assumed annual run hours, 8760 for continuous ventilation

Baseline Efficiencies

Baseline efficiency is assumed to be Vermont Residential Building Energy Code, which is 2.8 CFM/Watt.

High Efficiency

New efficient criteria is assumed to be 4.84 CFM/Watt for ENERGY STAR Vent Fans, and 12.48 CFM/Watt for ENERGY STAR Most Efficient Vent Fans.

Operating Hours

Continuous, 8760.

Load Shapes

25a Flat (8760 hours)

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
25	Flat (8760 hours)	Active	31.7 %	34.9 %	15.9 %	17.5 %	100.0 %	100.0 %

Net Savings Factors

Measures

VNTXCEIL	Exhaust fan, ceiling

Tracks [Base Track]

6018LINC [is base track]	LIMF NC
6019MFNC [is base track]	MF Mkt NC
6032EPEP [is base track]	Efficient Products - Residential
6034LISF [is base track]	LISF Retrofit
6036RETR [is base track]	Res Retrofit
6038VESH [is base track]	RNC VESH
5102OLS [5100EPEP]	Retail Efficient Products On-line Store

Persistence

The persistence factor is assumed to be one.

Lifetimes

19 years[4]

Analysis period is the same as the lifetime.

Measure Cost

Incremental cost per installed fan is $69.65 for quiet, efficient fans.[5]

O&M Cost Adjustments

Savings Summary

	ΔkW	ΔkWh
ENERGY STAR Vent Fan	0.008	66.0
ENERGY STAR Most Efficient Vent Fan	0.014	121.3

[6]

Fossil Fuel Description

Footnotes

[1] 50CFM is the closest available fan size to ASHRAE 62.2 Section 4.1 Whole House Ventilation rates based upon typical square footage and bedrooms.

[2] Average CFM/watt for ENERGY STAR certified fans from current Qualified Products List

[3] 2015 Vermont Resiential Business Energy Standard, Table R403.6.1 Mechanical Ventilation System Fan Efficacy

[4] Conservative estimate based upon GDS Associates Measure Life Report "Residential and C&I Lighting and HVAC measures" 25 years for whole-house fans, and 19 for thermostatically-controlled attic fans.

[5] NEEP Incremental Cost Study Phase Two, Page 34, Table 55. Costs are weighted averages based on ENERGY STAR QPL CFM model counts.

[6] Refer to analyis document: EVT_ENERGY STAR Ventilation Fan_Analysis_May 2017.xlsx.

Tank Wrap

Measure Number: **V-A-1 e**
Portfolio: 81
Status: Inactive
Effective Date: 2013/1/1
End Date: 2018/12/31
Program: Low Income Single Family
End Use: Hot Water

Referenced Documents

1. Pennsylvania Public Utility Commission Technical Reference Manual (PA TRM)
2. NREL, National Residential Efficiency Measures Database
3. Efficiency Vermont Program Documentation
4. DOE, "Residential Heating Products Final Rule Technical Support Document"

Description

Insulation "blanket" is wrapped around the outside of an existing electric hot water tank to reduce stand-by losses.

Estimated Measure Impacts

Average Annual MWH Savings per unit	Average number of measures per year	Average Annual MWh savings per year
0.113	100	11.3

Algorithms

Electric Demand Savings

For the prescriptive assumption, the assumed savings is:

$\Delta kW =$ 113 / 8760

$\Delta kW =$ **0.01289 kW**

ΔkW = ΔkWh 8760

Symbol Table

Electric Energy Savings

For the prescriptive assumption, 40 gallons is selected as an average tank[1], and the savings are derived from adding R-10 to an R-12 tank.

The prescriptive savings are therefore calculated as:

$\Delta kWh = ((23.18/12 – 25.31/22) * 55 * 8760) / (3412 * 0.98)$

$\Delta kWh =$ **113 kWh**

$\Delta kWh = ((U_{base}A_{base} – U_{insul}A_{insul}) \times \Delta T \times Hours) / (3412 \times \eta DHW)$

Where:

ΔkW	=	gross customer connected load kW savings for the measure
ΔkWh	=	gross customer annual kWh savings for the measure
ΔT	=	Average temperature difference between tank water and outside air temperature (°F) = 55°F[2]
ηDHW	=	Recovery efficiency of electric hot water heater = 0.98[3]
A_{base}	=	Surface area of storage tank prior to adding tank wrap (square feet) = 23.18[4]
A_{insul}	=	Surface area of storage tank after addition of tank wrap (square feet)

= 25.31[4]

ΔkWh = kWh savings from tank wrap installation, calcualted below

3412 = Conversion from BTU to kWh

8760 = Number of hours in a year (savings are from reduced standby loss and are therefore assumed to be constant over the year).

Hours = Number of hours in a year (since savings are assumed to be constant over year).

= 8760

U_{base} = Overall heat transfer coefficient prior to adding tank wrap (Btu/Hr-F-ft^2)

= 1/12[5]

U_{insul} = Overall heat transfer coefficient after addition of tank wrap (Btu/Hr-F-ft^2)

= 1/22[6]

Baseline Efficiencies

The baseline condition is a hot water tank that is not already well insulated. Newer, rigid, foam insulated tanks are considered to be effectively insulated while older tanks with fiberglass insulation that gives to gentle pressure are not.

High Efficiency

High efficiency is addition of R-10 insulation to hot water tank.

Operating Hours

8760, savings are from reduced standby loss and are therefore assumed to be constant over the year.

Load Shapes

25a Flat (8760 hours)

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
25	Flat (8760 hours)	Active	31.7 %	34.9 %	15.9 %	17.5 %	100.0 %	100.0 %

Net Savings Factors

Measures

HWEINSUL	Insulate hot water tank

Tracks [Base Track]

6034LISF [is base track]	LISF Retrofit

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
LISF Retrofit	6034LISF	HWEINSUL	1.00	1.00

Persistence

The persistence factor is assumed to be one.

Lifetimes

6 years (same as in DPS screening of Efficiency Utility Core programs).

Analysis period is the same as the lifetime.

Measure Cost

$35 average retrofit cost.[7]

O&M Cost Adjustments

N/A

Fossil Fuel Description

N/A

Footnotes

[1] DOE, "Residential Heating Products Final Rule Technical Support Document," Table 3.2.13, http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/htgp_finalrule_ch3.pdf

[2] Assumes 120°F water in the hot water tank and average temperature of basement of 65°F.

[3] NREL, National Residential Efficiency Measures Database, http://www.nrel.gov/ap/retrofits/measures.cfm?gId=6&ctId=40

[4] Assumptions from PA TRM. Area values were calculated from average dimensions of several commercially available units, with radius values measured to the center of the insulation. Area includes tank sides and top to account for typical wrap coverage.

[5] Conservative baseline assumption

[6] Efficiency Vermont program documentation specifies R-10 tank wrap

[7] Based on EVT online product review.

Tank Temperature Turn-Down

Measure Number: V-A-3 f
Portfolio: 81
Status: Inactive
Effective Date: 2013/1/1
End Date: 2018/12/31
Program: Low Income Single Family
End Use: Hot Water

Update Summary

Referenced Documents

1. Pennsylvania Public Utility Commission Technical Reference Manual (PA TRM).
2. NREL, National Residential Efficiency Measures Database
3. DOE, "Residential Heating Products Final Rule Technical Support Document," Table 3.2.13, http://www1.eere.energy.gov/buildings/appliance_standards/residential/pdfs/htgp_finalrule_ch3.pdf

- DHWConsSavingsWHEC10-12

Description

The domestic hot water tank thermostat is lowered to reduce standby losses.

Estimated Measure Impacts

Algorithms

Electric Demand Savings

Defaults:

$\Delta kW = 45.5 / 8760$

$= 0.00519$ kW

ΔkW	$= \Delta kWh / 8760$

Symbol Table

Electric Energy Savings

Defaults:

$\Delta kWh = ((1/20 * 23.18) * 15 * 8760) / (3412 * 0.98)$

$= 45.5$ kWh

For electric DHW systems:

ΔkWh	$= ((U_{base} \times A_{base}) \times \Delta T \times Hours) / (3412 \times \eta DHW)$

Symbol Table

Fossil Fuel Savings

Defaults:

$\Delta MMBtu\ \Delta = ((1/20 * 23.18) * 15 * 8760) / (1{,}000{,}000 * 0.76)$

$= 0.20$ MMBtu

For fossil fuel DHW systems:

ΔMMBtu	$= ((U_{base} \times A_{base}) \times \Delta T \times Hours) / (1{,}000{,}000 \times \eta DHW)$

Where:

ΔkW	=	Gross customer connected load kW savings for the measure.
ΔMMBtu	=	Gross customer annual MMBtu savings for the measure.
ΔT	=	Temperature difference between before and after turn down. = 15°F[1]

ηDHW	=	Recovery efficiency of electric water heater. = 0.98[2] Recovery efficiency of fossil fuel water heater = 0.76[2]
ΔkWh	=	Gross customer connected load kW savings for the measure.
1,000,000	=	Conversion from BTU to MMBtu.
3412	=	Conversion from BTU to kWh.
8760	=	Number of hours in a year (savings are from reduced standby loss and are therefore assumed to be constant over the year).
A_{base}	=	Surface area of storage tank (square feet). = 23.18[3]
Hours	=	Number of hours in a year (savings are assumed to be constant over year). = 8760
U_{base}	=	Overall heat transfer coefficient (Btu/Hr-F-ft^2). = 1/20[4]

Baseline Efficiencies

The baseline condition is a hot water tank with a thermostat setting that is higher than 125°F, typically 130°F or higher.

High Efficiency

High efficiency is a hot water tank with the thermostat set at 120°F or less.

Operating Hours

8766, savings are from reduced standby loss and are therefore assumed to be constant over the year.

Load Shapes

25a Flat (8760 hours)

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
25	Flat (8760 hours)	Active	31.7 %	34.9 %	15.9 %	17.5 %	100.0 %	100.0 %

Net Savings Factors

Measures

HWETEMPS	Hot water temperature setback

Tracks [Base Track]

6034LISF [is base track]	LISF Retrofit

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
LISF Retrofit	6034LISF	HWETEMPS	1.00	1.00

Persistence

The persistence factor is assumed to be one.

Lifetimes

2 years.

Analysis period is the same as the lifetime.

Measure Cost

$5 for contractor time.

O&M Cost Adjustments

There are no operation and maintenance cost adjustments for this measure

Fossil Fuel Description

Footnotes

[1] Assumes 135°F tank turned down to 120°F.

[2] NREL, National Residential Efficiency Measures Database, http://www.nrel.gov/ap/retrofits/measures.cfm?gId=6&ctId=40

[3] Area includes tank sides and top, for a 40 gallon tank. Assumptions from Pennsylvania Public Utility Commission Technical Reference Manual (PA TRM). Area values were calculated from average dimensions of several commercially available units, with radius values measured to the center of the insulation. Area includes tank sides and top to account for typical wrap coverage.

[4] Assumes an existing well insulated tank, or that tank wrap is added at that same time as the turn-down. Assumptions from Pennsylvania Public Utility Commission Technical Reference Manual (PA TRM).

Freezer Early Replacement

Measure Number:	**V-E-2 c**
Portfolio:	94
Status:	Active
Effective Date:	2016/1/1
End Date:	[None]
Program:	Low Income Single Family
End Use:	Refrigeration

Update Summary

Update of high efficiency specification. Split measure savings assumption in to pre-1993 and 1993-2001 bins so that savings can be claimed based on age of the equipment. Change from market opportunity to early replacement measure.

Applicable Markets

Applicable Markets
Multifamily
Low Income Single Family
Existing Homes

Referenced Documents

- 2009 VT Appliance Data_TRMCostAnalysis
- Refrigerator kW Calculations
- 2003 D&R Int. Freezer Fact Sheet
- 2016 Freezer Savings.xls

Description

An ENERGY STAR qualifying residential freezer is installed replacing an existing unit. Units must be pre-1993 in order to be eligible for early replacement. If age is unknown, the units can be metered to determine consumption. If metering indicates an annual consumption of ≥990 kWh or a savings of ≥565kWh, the measure is eligible. Eligibility can also be based upon a visual inspection, where the unit appears to be in poor condition such as leaking seals or warped doors. In this instance a reduced savings (based on 1993-2001 units) should be claimed.

Algorithms

Electric Demand Savings

ΔkW	$= \Delta kWh/Hours$
$\Delta kW_{\text{Pre-1993 units for remaining life of existing unit (6 years)}}$	= 565.2/8477 = **0.0667 kW**
$\Delta kW_{\text{Pre-1993 units for remaining measure life}}$	= 49.2/8477 = **0.0058 kW**
$\Delta kW_{\text{1993 - 2001 units for remaining life of existing unit (6 years)}}$	= 319.4/8477 = **0.0377 kW**
$\Delta kW_{\text{1993-2001 units for remaining measure life}}$	= 49.2/8477 = **0.0058 kW**

Symbol Table

Electric Energy Savings

ΔkWh	$= kWh_{EXIST} - kWh_{ESTAR}$ (for remaining life of existing unit (1st 6 years)) $= kWh_{base} - kWh_{ESTAR}$ (for remaining measure life)
$\Delta kWh_{\text{Pre-1993 units for remaining life of existing unit (1st 6 years)}}$	= 989.9 - 424.7 = 565.2 kWh
$\Delta kWh_{\text{Pre-1993 units for remaining measure life}}$	= 473.9 - 424.7 = 49.2 kWh
$\Delta kWh_{\text{1993- 2001 units for remaining life of existing unit (1st 6 years)}}$	= 744.1 - 424.7 = 319.4 kWh

$\Delta kWh_{1993\text{-}2001 \text{ for remaining measure life}}$	= 473.9 - 424.7 = 49.2 kWh

Where:

ΔkW = gross customer connected load kW savings for the measure

ΔkWh = gross customer annual kWh savings for the measure

ΔkWh = gross customer annual kWh savings for the measure

Hours = Equivalent Full Load Hours
= 8477[1]

kWh_{base} = Baseline kWh consumption per year
= 473.9 kWh[2]

kWh_{ESTAR} = ENERGY STAR kWh consumption per year
= 424.7 kWh[3]

kWh_{EXIST} = Assumed kWh consumption of existing unit being replaced
Pre-1993 units = 989.9kWh[4]
1993-2001 units = 744.1kWh[5]

Mid Life Savings Adjustment

For early replacement measures a mid life adjustmet of 49.2/565.2 = 8.7% will be applied after 6 years for pre-1993 units and 49.2/319.4 = 15.4% for 1993-2001 units.

Baseline Efficiencies

Baseline efficiency for the first six years is an existing pre-1993 freezer meeting the minimum federal standard effective in 1990 (except for units eligible via visual inspection only, where a 1993-2001 freezer is assumed based on federal standard effective in 1993). After that the baseline is a new refrigerator meeting the minimum federal efficiency standard effective September 15th, 2014.

High Efficiency

The High Efficiency level is a freezer meeting ENERGY STAR specifications for efficiency established September 15, 2014 (at least 10% more.efficient than federal standard units).

Load Shapes

4b Residential Refrigerator

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
4	Residential Refrigerator	Active	30.8 %	33.0 %	17.1 %	19.1 %	79.6 %	100.0 %

Net Savings Factors

Measures

RFRESFZR Energy star freezer, early replacement

Tracks [Base Track]

6034LISF [is base track] LISF Retrofit

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
LISF Retrofit	6034LISF	RFRESFZR	1.00	1.00

Persistence

The persistence factor is assumed to be one.

Lifetimes

For early replacement measures, the remaining useful life of the existing unit is assumed to be 6 years. For market opportunity measures lifetime is assumed to be 16 Years.[6] Analysis period is the same as the lifetime.

Measure Cost

The full cost for an ENERGY STAR unit is $500. The cost of a baseline replacement freezer is $465.[7]

O&M Cost Adjustments

There are no operation and maintenance cost adjustments for this measure.

Fossil Fuel Description

There are no fossil fuel algorithms or default values for this measure.

Footnotes

[1] The Summer and Winter Coincident kW are calculated using an algorithm for the kW during any hour (or group of hours) from the California study; Cadmus Group; "Residential Retrofit High Impact Measure Evaluation Report", Feb 8, 2010. To calculate an Equivalent Full Load Hours the UEC (* PartUse) is divided by the summer coincident kW (956 * .779)/0.088 = 8477 hours. The summer coincidence factor is therefore assumed to be 1.0 and a winter coincidence factor calculated as the relative winter to summer kW result from the algorithm. For the calculation see "Refrigerator kW Calculations.xls".

[2] Average equivalent current Federal Standard consumption value for all units on ENERGY STAR qualified list accessed 06/2016. See "2016 Freezer Savings.xls".

[3] Average of units on ENERGY STAR qualified list accessed 06/2016. See "2016 Freezer Savings.xls".

[4] Average equivalent 1990 Federal Standard consumption for all units on ENERGY STAR qualified list, accessed 06/2016. See "2016 Freezer Savings.xls".

[5] Average equivalent 1993 Federal Standard consumption for all units on ENERGY STAR qualified list, accessed 06/2016. See "2016 Freezer Savings.xls".

[6] Source: 2003 D&R Int. Freezer Fact Sheet

[7] Based on review of data from the Northeast Regional ENERGY STAR Consumer Products Initiative; "2009 ENERGY STAR Appliances Practices Report", submitted by Lockheed Martin, December 2009. See 2009 VT Appliance Data_TRMCostAnalysis.xlsfor data.

Domestic Hot Water Recirculation Pipe Insulation

Measure Number:	III-D-7 a
Portfolio:	74
Status:	Active
Effective Date:	2012/1/1
End Date:	[None]
Program:	Multifamily
End Use:	Hot Water

Referenced Documents

- Domestic Water Re-heat_MF
- measure_life_GDS[1]
- MeasureCost_StevePitkin6-15-11

Description

Domestic Hot Water Recirculation Pipe that is continuously circulating is insulated with 1.5 or 2 inches of insulation instead of a baseline level of 0.5 inch.

Estimated Measure Impacts

	Average Annual Savings per unit		Average number of measures per year	Average Annual MWh savings per year	
Domestic Hot Water Recirculation Pipe Insulation	MWH	MMBtu		MWH	MMBtu
		12	25		300

Algorithms

Fossil Fuel Savings

Deemed fossil fuel savings per linear foot of DHW circulation pipe are provided in the Fossil Fuel Descriptions section below.

Baseline Efficiencies

Domestic Hot Water Recirculation Pipe insulated with 0.5 inch of insulation.

High Efficiency

Domestic Hot Water Recirculation Pipe insulated with 1.5 or 2 inches of insulation.

Operating Hours

Load Shapes

25a Flat (8760 hours)

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
25	Flat (8760 hours)	Active	31.7 %	34.9 %	15.9 %	17.5 %	100.0 %	100.0 %

Net Savings Factors

Measures

HWERECIN	Domestic Hot Water Recirculation Pipe

Tracks [Base Track]

6018LINC [is base track]	LIMF NC
6019MFNC [is base track]	MF Mkt NC

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over

LIMF NC	6018LINC	HWERECIN	1.00	1.00
MF Mkt NC	6019MFNC	HWERECIN	1.00	1.00

Persistence

The persistence factor is assumed to be one.

Lifetimes

20 years[1].

Analysis period is the same as the lifetime.

Measure Cost

The incremental cost is assumed to be $0.50 per linear foot for 1.5 inch pipe insulation and $1.0 per linear foot for 2 inch pipe insulation[2].

O&M Cost Adjustments

Fossil Fuel Description

Deemed fossil fuel savings per linear foot of DHW circulation pipe are provided below[3].

DHW fuel source	MMBtu Savings for Insulation Thickness per Linear Foot	
	1.5"	2"
Natural Gas or LP	0.0382	0.0443
Oil	0.0422	0.049

Assumes an average 1" circulation pipe. The boiler efficiency is assumed to be Tier 1 standard (i.e. 94% for gas, 85% for oil). Savings are based on the following pipe heat loss table[4]:

Insulation Thickness	Pipe Heat Loss (btu/lf-yr)				
	1/2"	3/4"	1"	1-1/4"	1-1/2"
Bare Pipe	181,300	218,900	265,700	325,800	367,200
0.5	59,750	67,800	79,320	98,350	110,400
1	42,440	50,990	53,010	68,110	68,980
1.5	34,540	40,000	43,440	48,510	54,880
2	30,620	34,830	37,660	44,650	43,570
2.5	26,750	29,910	33,910	39,460	39,470

Footnotes

[1] Consistent with GDS Associates 2007 "Measure Life Report"; http://neep.org/uploads/EMV%20Forum/EMV%20Studies/measure_life_GDS%5B1%5D.pdf

[2] Cost estimates provided by Steve Pitkin, construction project manager and cost estimator. See 'MeasureCost_StevePitkin6-15-11.xls' for more information.

[3] Calculated using EVT developed spreadsheet tool ‘Domestic Water Re-heat_MF.xls’.

[4] Taken from free software called “3EPlusv4” developed by NAIMA, the North American Insulation Manufacturer's Association. The delta T used to develop the pipe heat loss table was 50 degrees (120 degree water in the pipe and 70 degree ambient temperature). The software can be download here:

http://www.pipeinsulation.org/pages_v4/download.html

Boiler Hot Water Distribution Pipe Insulation

Measure Number: III-D-8 a
Portfolio: 74
Status: Active
Effective Date: 2012/1/1
End Date: [None]
Program: Multifamily
End Use: Hot Water

Referenced Documents

- measure_life_GDS[1]
- MeasureCost_StevePitkin6-15-11
- Boiler_Distribution_pipe_insulation
- Boiler with Reset_Hot Water Temp

Description

Boiler hot water recirculation pipe that is continuously circulating during the heating season (assumed to be when outside temperature is about 65 degrees F) is insulated with 1.5 or 2 inches of insulation instead of a baseline level of 1 inch.

Estimated Measure Impacts

	Average Annual Savings per unit		Average number of measures per year	Average Annual MWh savings per year	
Boiler Recirculation Pipe Insulation	MWH	MMBtu		MWH	MMBtu
		7.8	25		195

Algorithms

Fossil Fuel Savings

Deemed values presented below. For calculation see Boiler_Distribution_Pipe Insulation.xls.

DHW fuel source	MMBtu Savings for Insulation Thickness per Linear Foot	
	1.5”	2”
Gas (no reset control)	0.022	0.032
Oil (no reset control)	0.024	0.036
Gas (with reset control)	0.013	0.019
Oil (with reset control)	0.017	0.025

MMBtu/ft = ((Circulation Temp - Ambient Temp) x Operating Hours x (U_{Base} – U_{Eff}) × SA/ft) / µHeat / 1,000,000

Where:

µHeat = Boiler efficiency assumed to be Tier 1 standard = 94% for gas, 85% for oil

Ambient Temp = 65°F

Circulation Temp = No reset control = 180°F
Gas boilers w/reset = 132°F
Oil boilers w/reset = 146°F[1]

MMBtu/ft =

Operating Hours = 6260[2]

SA/ft = Surface Area per foot of pipe

U_{Base} = U Factor of 1” insulation = 1/3.5 = 0.286

U_{Eff} = U Factor of 1.5” or 2” insulation = 0.190 (1/(3.5*1.5)) or 0.143 (1/(3.5*2))

Baseline Efficiencies

Boiler Hot Water Recirculation Pipe insulated with 1 inch of insulation as required by CBES 2011 code.

High Efficiency

Boiler Hot Water Recirculation Pipe insulated with 1.5 or 2 inches of insulation.

Operating Hours

Load Shapes

N/A

Net Savings Factors

Measures

HWEBREIN	Boiler Hot Water Recirculation Pipe

Tracks [Base Track]

6018LINC [is base track]	LIMF NC
6019MFNC [is base track]	MF Mkt NC

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
LIMF NC	6018LINC	HWEBREIN	1.00	1.00
MF Mkt NC	6019MFNC	HWEBREIN	1.00	1.00

Persistence

The persistence factor is assumed to be one.

Lifetimes

20 years[3].

Analysis period is the same as the lifetime.

Measure Cost

The incremental cost is assumed to be $0.50 per linear foot for 1.5 inch pipe insulation and $1.0 per linear foot for 2 inch pipe insulation[4].

O&M Cost Adjustments

Fossil Fuel Description

Footnotes

[1] Circulation temperatures for boilers with reset controls were calculated assuming 180°F water when outside air is below zero and at 60°F outside air we assume reset controls reduce the temperature to 100°F for gas-fired boilers and 140°F for oil (typically oil boilers are not reset as much as gas boilers due to thermal and condensing issues), and assume a linear relationship between those two points. See ‘Boiler with Reset_Hot Water Temp.xls’ for calculation.

[2] Number of hours where outside temperature is below 60°F, based on Bin Analysis see Pipe Insulation.xls.

[3] Consistent with GDS Associates 2007 “Measure Life Report”; http://neep.org/uploads/EMV%20Forum/EMV%20Studies/measure_life_GDS%5B1%5D.pdf

[4] Cost estimates provided by Steve Pitkin, construction project manager and cost estimator. See ‘MeasureCost_StevePitkin6-15-11.xls’ for more information.

Drain Water Heat Recovery Device

Measure Number: **III-D-9 a**
Portfolio: 74
Status: Active
Effective Date: 2012/1/1
End Date: [None]
Program: Multifamily
End Use: Hot Water

Referenced Documents

- Drain Water Heat Recovery Characterization and Modeling
- DWHR Calculator

Description

Drain water heat exchanger installed to capture and reuse energy from main drain pipe to preheat incoming cold water to water heater and shower. This measure is only applicable to units serving 2 or more apartments and is not supported for buildings with natural gas since it has been found to not be cost effective.

Estimated Measure Impacts

Algorithms

Electric Energy Savings

Energy Savings calculations based on *Drain Water Heat Recovery Characterization and Modeling – Final Report, C. Zaloum, M. Lafrance, J Gusdorf, 2007*,p. 29

$$\Delta kWh = (0.017 \times \varepsilon \times 8.623 \times HS \times 365 / (DHWe)) \times FLAG$$

Symbol Table

Fossil Fuel Savings

$$\Delta MMBtu = (0.017 \times \varepsilon \times 8.623 \times HS \times 365 / DHWe) \times 0.003412 \times (1\text{-}FLAG)$$

Where:

ΔkWh = gross customer annual kWh savings for the measure (kWh)
ΔMMBtu = Annual MMBtu fossil fuel savings per residential unit for the measure
ε = Drain Water Heat Recovery device efficiency[1]
0.003412 = Converts kWh to MMBtu
0.017 = 60/1000/3.6 (minutes/watts/megajoules)
365 = Days per year
8.623 = Heat Flux[2]
DHWe = Fuel Domestic Hot Water Recovery Efficiency = 86% if gas, 78% if oil[3]
FLAG = 1 if domestic hot water system is electric; 0 otherwise
HS = Household/Apartment Shower Minutes/Day [(Bedrooms + 1) x 5.3[4]]

Baseline Efficiencies

The baseline condition is an existing or proposed main drain pipe without heat recovery.

High Efficiency

High efficiency is installation of drain water heat recovery device.

Operating Hours

Load Shapes

8a Residential DHW conserve

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
8	Residential DHW conserve	Active	48.7 %	29.1 %	14.3 %	7.9 %	40.1 %	20.3 %

Net Savings Factors

Measures

HWEDRAIN	Drain Water Heat Recovery

Tracks [Base Track]

6018LINC [is base track]	LIMF NC
6019MFNC [is base track]	MF Mkt NC

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
LIMF NC	6018LINC	HWEDRAIN	1.00	1.00
MF Mkt NC	6019MFNC	HWEDRAIN	1.00	1.00

Persistence

The persistence factor is assumed to be one.

Lifetimes

25 years[5]

Measure Cost

The incremental cost for drain water heat recovery device varies based on the length of the device and the application.

O&M Cost Adjustments

There are no operation and maintenance cost adjustments for this measure

Fossil Fuel Description

See Fossil Fuel Savings algorithm above.

Footnotes

[1] For example efficiencies see Zaloum, Lafrance, Gusdorf , p. 13.

[2] Assumed Showerhead flow of 1.5 gpm, Incoming Cold Water Temp of 55°F, Shower Water Temp of 105°F and a drop of 6°F from shower to drain. See ‘DWHR Calculator.xls’ for details of the calculation.

[3] Assume Tier 1 efficiency level boilers (94% gas or 85% oil) with indirect water heaters (efficiency assumed to be 0.92 * boiler efficiency).

[4] 5.3 minutes per person per day is derived from EPA WaterSense document (http://www.epa.gov/watersense/docs/home_suppstat508.pdf) which suggests 11.6 gallons of water per person per day for shower use. This was based on a 1999 study (http://www.waterrf.org/ProjectsReports/PublicReportLibrary/RFR90781_1999_241A.pdf) that metered 1088 households for 4 weeks. The average flow rate for these showers was 2.2 gpm making the number of minutes per day 11.6/2.2 = 5.27 minutes.

[5] Conservative estimate based on product manufacturer published expected lifetime.

MultiFamily Lighting Fixtures

Measure Number:	III-A-2 e
Portfolio:	EVT TRM Portfolio 2017-10
Status:	Active
Effective Date:	2018/1/1
End Date:	[None]
Program:	Multifamily
End Use:	Lighting

Update Summary

This measure is updated to contain the common LED fixtures now used in the MF program. The assumptions are largely consistent with the Commercial "LED Lighting Systems" TRM, but apply a mixed baseline including 25% baseline lamps.

Referenced Documents

- MF LED Fixture Assumptions

Description

This measure characterization describes savings assumptions for typical fixtures beyond those characterized in the Efficient Products "Solid State (LED) Fixtures" measure, installed through the Multi Family program. All measures are considered Market Opportunity.

Baseline Efficiencies

The 2015 Vermont RBES requires 75% of fixtures to have high efficacy lamps. For fixtures within the Multifamily New Construction programs, Efficiency Vermont will therefore assume a baseline made up of 75% high efficacy as defined by the RBES and consistent with the C&I 'LED Lighting Systems' baseline assumptions, and 25% baseline EISA-qualified wattages that produce similar lumen output.

High Efficiency

High efficiency is an LED fixture listed on the DesignLights Consortium Qualified Products List.

Algorithms

Electric Demand Savings

ΔkW $= ((Watts_{BASE} - Watts_{EE})/1000) \times ISR \times WHF_d$

Symbol Table

Electric Energy Savings

ΔkWh $= ((Watts_{BASE} - Watts_{EE})/1000) \times HOURS \times ISR \times WHFe$

Where:

ΔkW = gross customer connected load kW savings for the measure

ΔkWh = gross customer annual kWh savings for the measure

HOURS = average hours of use per year (dependent on fixture location):

Fixture Location	Annual Hours of Use (HOURS)
In-unit	1,204.5[1]
Indoor Hallway / Stairway or Corridor	8,760
Laundry and other Common Areas	4,380[2]
Exterior Tenant Controlled	2,007.5[3]
Exterior Master Controlled	3,960[4]

ISR = in service rate or the percentage of units rebated that actually get used

= 1.0

$Watts_{BASE}$ = Baseline connected wattage from table located in Reference Tables section.

$Watts_{EE}$ = Energy efficient connected wattage from table located in Reference Tables section.

WHF_d = Waste heat factor for demand to account for cooling savings from efficient lighting. For MF this is assumed to be 1.0.

WHFe = Waste heat factor for energy to account for cooling savings from efficient lighting. For MF this is assumed to be 1.0.

Baseline Adjustment

Since 25% of each baseline fixture is an EISA compliant halogen bulb, and from 2020 the EISA regulation prohibits sale of any bulb with an efficacy lower than 45 lumens per watt, it is assumed that the savings become 100% of the T8 or CFL baseline from 2021[5]. Therefore a midlife baseline adjustment as provided below will be applied in 2021:

		Midlife Adjustment in 2021
LED Category	LED Measure Description	(DLC Blended)
LED Troffers	LED 2x2 Recessed Light Fixture, 2000-3500 lumens	57%
	LED 2x2 Recessed Light Fixture, 3501-5000 lumens	62%
	LED 2x4 Recessed Light Fixture, 3000-4500 lumens	40%
	LED 1x4 Recessed Light Fixture, 1500-3000 lumens	24%
	LED 1x4 Recessed Light Fixture, 3001-4500 lumens	39%
LED Linear Ambient Fixtures	LED Surface & Suspended Linear Fixture, <= 3000 lumens	28%
	LED Surface & Suspended Linear Fixture, 3001-4500 lumens	41%
LED Exterior Fixtures	LED Exterior Fixtures, <= 2,000 lumens	68%
	LED Exterior Fixtures, 2,001-5,000 lumens	63%

Load Shapes

Assume 'Residential Indoor Lighting' for in-unit fixtures, 'Flat (8760 hours)' for Indoor Hallway / Stairway or Corridor, 'Commercial Indoor Lighting-Blended' for other common area fixtures, 'Residential Outdoor Lighting' for tenant controlled exterior lighting and 'Commercial Outdoor Lighting' for master controlled exterior lighting.

1a Residential Indoor Lighting
2a Residential Outdoor Lighting
12d Commercial Indoor Lighting - Blended
13a Commercial Outdoor Lighting
25a Flat (8760 hours)

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
1	Residential Indoor Lighting	Active	36.9 %	35.0 %	13.0 %	15.1 %	29.8 %	8.2 %
2	Residential Outdoor Lighting	Active	20.5 %	50.6 %	6.1 %	22.8 %	34.6 %	1.8 %
12	Commercial Indoor Lighting - Blended	Active	48.8 %	19.5 %	22.2 %	9.5 %	46.9 %	67.9 %
13	Commercial Outdoor Lighting	Active	20.5 %	50.6 %	6.1 %	22.8 %	70.2 %	3.7 %
25	Flat (8760 hours)	Active	31.7 %	34.9 %	15.9 %	17.5 %	100.0 %	100.0 %

Net Savings Factors

Measures

LFH22LED	LED 2x2 Recessed Light Fixture
LFH24LED	LED 2x4 Recessed Light Fixture
LFH14LED	LED 1x4 Recessed Light Fixture
LFHSLLED	LED Linear Ambient Fixture
LFHEXLED	LED Exterior Fixtures

Tracks [Base Track]

6018LINC [is base track]	LIMF NC
6019MFNC [is base track]	MF Mkt NC
6017PRES [is base track]	6017PRES
6017CUST [is base track]	6017CUST
6017BPUF [6017PRES]	Building Performance (6017)

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
LIMF NC	6018LINC	LFH22LED	0.95	1.05
LIMF NC	6018LINC	LFH24LED	0.95	1.05
LIMF NC	6018LINC	LFH14LED	0.95	1.05

LIMF NC	6018LINC	LFHSLLED	0.95	1.05
LIMF NC	6018LINC	LFHEXLED	0.95	1.05
MF Mkt NC	6019MFNC	LFH22LED	0.95	1.05
MF Mkt NC	6019MFNC	LFH24LED	0.95	1.05
MF Mkt NC	6019MFNC	LFH14LED	0.95	1.05
MF Mkt NC	6019MFNC	LFHSLLED	0.95	1.05
MF Mkt NC	6019MFNC	LFHEXLED	0.95	1.05
6017PRES	6017PRES	LFH22LED	1.00	1.00
6017PRES	6017PRES	LFH24LED	1.00	1.00
6017PRES	6017PRES	LFH14LED	1.00	1.00
6017PRES	6017PRES	LFHSLLED	1.00	1.00
6017PRES	6017PRES	LFHEXLED	1.00	1.00
6017CUST	6017CUST	LFH22LED	1.00	1.00
6017CUST	6017CUST	LFH24LED	1.00	1.00
6017CUST	6017CUST	LFH14LED	1.00	1.00
6017CUST	6017CUST	LFHSLLED	1.00	1.00
6017CUST	6017CUST	LFHEXLED	1.00	1.00

Persistence

The persistence factor is assumed to be one.

Lifetimes

For Fixtures: 15 years

Analysis period is the same as lifetime.

Measure Cost

All measure costs are assumed to be incremental costs vs. the market opportunity baselines. LED costs are based on recent Efficiency Vermont experience and cost estimates provided by the U.S. Department of Energy. Refer to Reference Tables section of this document for incremental measure cost assumptions.

O&M Cost Adjustments

Baseline replacement costs are assumed equal to the T8 or pin based CFL cost for conservatism and simplicity.

		LED New and Baseline O&M Assumptions							
LED Category	**LED Measure Description**	**LED Lamp Life (hrs)**	**LED Lamp Replacement Cost**	**LED Driver Life (hrs)**	**LED Driver Replacement Cost**	**Baseline Lamp Life (hrs)**	**Baseline Lamp Replacement Cost Combined**	**Baseline Ballast Life (hrs)**	**Baseline Ballast Replacement Cost Combined**
LED Troffers	LED 2x2 Recessed Light Fixture, 2000-3500 lumens	50,000	$78.30	70,000	$40.00	24,000	$26.33	40,000	$35.00
	LED 2x2 Recessed Light Fixture, 3501-5000 lumens	50,000	$87.76	70,000	$40.00	24,000	$39.50	40,000	$35.00
	LED 2x4 Recessed Light Fixture, 3000-4500 lumens	50,000	$95.49	70,000	$40.00	24,000	$12.33	40,000	$35.00
	LED 1x4 Recessed Light Fixture, 1500-3000 lumens	50,000	$65.43	70,000	$40.00	24,000	$6.17	40,000	$35.00
	LED 1x4 Recessed Light Fixture, 3001-4500 lumens	50,000	$99.99	70,000	$40.00	24,000	$12.33	40,000	$35.00
LED Linear Ambient Fixtures	LED Surface & Suspended Linear Fixture, <= 3000 lumens	50,000	$62.05	70,000	$40.00	24,000	$6.17	40,000	$35.00
	LED Surface & Suspended Linear Fixture, 3001-4500 lumens	50,000	$93.14	70,000	$40.00	24,000	$12.33	40,000	$35.00
LED Exterior Fixtures	LED Exterior Fixtures, <= 2,000 lumens	50,000	$55.57	70,000	$62.50	15,000	$9.17	40,000	$50.00
	LED Exterior Fixtures, 2,001-5,000 lumens	50,000	$81.46	70,000	$62.50	15,000	$58.00	40,000	$102.50

Reference Tables

LED New and Baseline Assumptions[6]

LED Category	LED Measure Description	WattsEE (DLC Blended)	Multi Family Baseline Description	WattsBASE	Delta Watts (DLC Blended)	Incremental Cost[7]	Measure Code
LED Troffers	LED 2x2 Recessed Light Fixture, 2000-3500 lumens	25.4	(0.75 * T8 U-Tube 2L-FB32 w/ Elec - 2') + (0.25 * 3 * 53W halogens)	84.0	58.6	$46	LFH22LED
	LED 2x2 Recessed Light Fixture, 3501-5000 lumens	36.7	(0.75 * T8 U-Tube 3L-FB32 w/ Elec - 2') + (0.25 * 3 * 72W halogens)	120.0	83.3	$56	LFH22LED
	LED 2x4 Recessed Light Fixture, 3000-4500 lumens	33.3	(0.75 * T8 2L-F32 w/ Elec - 4') + (0.25 * 3 * 72W halogens)	98.3	65.0	$44	LFH24LED
	LED 1x4 Recessed Light Fixture, 1500-3000 lumens	21.8	(0.75 * T8 1L-F32 w/ Elec - 4') + (0.25 * 3 * 53W halogens)	63.8	42.0	$23	LFH14LED
	LED 1x4 Recessed Light Fixture, 3001-4500 lumens	33.7	(0.75 * T8 2L-F32 w/ Elec - 4') + (0.25 * 3 * 72W halogens)	98.3	64.6	$63	LFH14LED
LED Linear Ambient Fixtures	LED Surface & Suspended Linear Fixture, <= 3000 lumens	19.5	(0.75 * T8 1L-F32 w/ Elec - 4') + (0.25 * 3 * 53W halogens)	63.8	44.3	$13	LFHSLLED
	LED Surface & Suspended Linear Fixture, 3001-4500 lumens	32.1	(0.75 * T8 2L-F32 w/ Elec - 4') + (0.25 * 3 * 72W halogens)	98.3	66.2	$43	LFHSLLED
LED Exterior Fixtures	LED Exterior Fixtures, <= 2,000 lumens	15.8	(0.75 * 42W 4-pin CFL) + (0.25 * 2 * 53W halogens)	61.8	46.0	$85	LFHEXLED
	LED Exterior Fixtures, 2,001-5,000 lumens	35.8	(0.75 * 100W Metal Halide) + (0.25 * 2 * 150W halogens)	160.2	124.4	$111	LFHEXLED

The resulting deemed prescriptive savings are provided below:

LED Category	LED Measure Description	ΔkW	ΔkWh				
			In-Unit	Indoor Hallway / Stairway or Corridor	Laundry and other Common Areas	Exterior Tenant Controlled	Exterior Master Controlled
LED Troffers	LED 2x2 Recessed Light Fixture, 2000-3500 lumens	0.0586	70.6	513.3	256.7	117.6	232.1
	LED 2x2 Recessed Light Fixture, 3501-5000 lumens	0.0833	100.3	729.7	364.9	167.2	329.9
	LED 2x4 Recessed Light Fixture, 3000-4500 lumens	0.0650	78.2	569.0	284.5	130.4	257.2
	LED 1x4 Recessed Light Fixture, 1500-3000 lumens	0.0420	50.5	367.5	183.7	84.2	166.1
	LED 1x4 Recessed Light Fixture, 3001-4500 lumens	0.0646	77.8	565.5	282.7	129.6	255.6
LED Linear Ambient Fixtures	LED Surface & Suspended Linear Fixture, <= 3000 lumens	0.0443	53.3	387.6	193.8	88.8	175.2
	LED Surface & Suspended Linear Fixture, 3001-4500 lumens	0.0662	79.7	579.5	289.7	132.8	262.0
LED Exterior Fixtures	LED Exterior Fixtures, <= 2,000 lumens	0.0460	55.3	402.5	201.3	92.2	182.0
	LED Exterior Fixtures, 2,001-5,000 lumens	0.0859	103.5	752.5	376.2	172.4	340.2

Footnotes

[1] Based on average daily hours of use of 3.3, from Table 3-5, page 43, value for Living Space for Upstate New York, from NMR Group, Inc., Northeast Residential Lighting Hours-of-Use Study.

[2] Assumes 12 hours per day.

[3] Based on average daily hours of use of 5.5 exterior, from Table 3-1, page 34 for Upstate New York from NMR Group, Inc., Northeast Residential Lighting Hours-of-Use Study.

[4] Commercial hours based on 3-year weighted average for fixtures rebated through Efficiency Vermont's Business Energy Services prescriptive program, through 12/14/2015. See Rx_C&I_LED_hours.xlsx for analysis

[5] In recognition of the likely reality that significant volumes of lower performing products will remain in the market beyond 2020, that there will be no or minimal enforcement, and the political uncertainty surrounding upcoming efficiency regulations, DCSEU will model the shift to a baseline of 45 lumens per watt starting in 2021.

[6] Efficient wattages and the 75% baseline wattage are consistent with the Commercial LED Lighting Systems measure. See that measure and the attached "LED Lighting Systems TRM Assumptions 2017.xlsx" for details on how these assumptions were determined. The blending of the 25% halogen baseline is performed in "MF Fixture Assumptions.xlsx".

[7] Incremental cost assumptions are based upon taking 75% of the incremental costs determined in the commercial "LED Lighting Systems" measure and 25% of the incremental cost of omnidirectional led lamps over halogen ($8.50 per lamp).

Comprehensive Thermal Measure

Measure Number: III-F-3 c
Portfolio: EVT TRM Portfolio 2018-12
Status: Active
Effective Date: 2018/1/1
End Date: [None]
Program: Multifamily
End Use: Space Heating

Update Summary

December 2018 - this update aligns TRM content with how the 2018 program and process operates.

Referenced Documents

- MeasureCost_StevePitkin6-15-11
- EVT Multifamily New Construction Minimum Requirements

Description

This measure characterization describes the analytical approach for a package of shell and HVAC measures performed to meet the requirements of the Efficiency Vermont Multifamily New Construction and Major Rehabilitation Program. The program incentivizes projects meeting requirements for one of three tracks: Electric Only, Efficiency Vermont Certified, and High-Performance.

This characterization is intended to capture a high level analytical approach for the program. Typically, all components of an analysis with the exception of incremental cost assignment is performed on a site-specific, custom basis. Thus, the utility of this characterization in relation to project analysis is limited to establishing incremental costs.

Estimated Measure Impacts

Algorithms

Energy and Demand Savings

Energy (kWh and MMBtu) and Demand (kW) savings will be calculated on a custom basis, typically using EVT's QLoss tool. Historically REMRate was employed for analytical purposes, however recent guidance from the program's developers has cautioned against using it to model larger multifamily buildings. To do so confidently, individual units would need to be modeled separately, which is prohibitively expensive for EVT from a resource standpoint. For a fee, REMRate will be used upon customer request, if for example ENERGY STAR certification is being pursued.

Baseline Efficiencies

Vermont’s 2015 Residential Building Energy Standards (30 V.S.A. § 51) apply and serve as baseline project requirements, except in instances where 2015 Commercial Building Energy Standards apply. RBES 2015 gives five prescriptive package options to meet compliance. For any project, the relevant baseline as chosen and indicated by the customer is used to estimate impacts. In practice, it has been observed that the majority of customers chose Package 4.

High Efficiency

Minimum program requirements must be met to qualify for incentive (see referenced document EVT Multifamily New Construction Minimum Requirements). Actual project-specific specifications will be used for impact analysis.

Operating Hours

Load Shapes

Custom loadshapes will be used as appropriate and necessary. Typically, however, measures use one of the following default loadshapes.

7a Residential DHW insulation
11a Residential A/C
5b Residential Space heat

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
7	Residential DHW insulation	Active	31.7 %	34.9 %	15.9 %	17.5 %	100.0 %	100.0 %
11	Residential A/C	Active	0.7 %	2.8 %	53.3 %	43.2 %	0.0 %	82.9 %
5	Residential Space heat	Active	42.9 %	57.1 %	0.0 %	0.0 %	25.0 %	0.0 %

Net Savings Factors

Measures

TSHCOMPH	Comprehensive Thermal Measure REMRate Calculated H
TSHCOMPC	Comprehensive Thermal Measure REMRate Calculated C
HWECOMP1	Comprehensive Thermal Measure REMRate Calculated D

Tracks [Base Track]

6018LINC [is base track]	LIMF NC
6019MFNC [is base track]	MF Mkt NC

Persistence

The persistence factor is assumed to be one.

Lifetimes

(Consistent with lifetime estimates used by Efficiency Vermont in the state screening tool.)

Heating Savings: 25 years

AC Savings: 15 years

DHW Savings: 15 years

Analysis period is the same as the lifetime.

Measure Cost

EVT Certified Comprehensive Thermal Package

	Incremental Cost Assumption Per Unit					
Number of Units	1-5	6-10	11-15	16-20	21-25	26+
Heating Savings (heating system and shell upgrades)	$ 2,554	$2,159	$1,764	$1,369	$974	$500
Air Conditioning Savings (AC systems)	$300	$270	$240	$211	$181	$145
DHW Savings	$0	$0	$0	$0	$0	$0
Total Cost (with cooling)	$2,854	$2,429	$2,004	$1,580	$1,155	$731
Total Cost (without cooling)	$2,554	$2,159	$1,764	$1,369	$974	$500

Notes:

1. Incremental costs used are based on the least expensive options provided, since this is the cost required to meet approved efficiency levels. Any costs associated with alternate decisions that the participant may make to achieve similar efficiency levels are not be included.

2. DHW Savings has a zero measure cost since there is no increment in cost between an indirect tank off a 84% boiler or an indirect tank off a 94% boiler. The incremental cost of the boiler itself is captured in the heating savings.

3. Incremental costs were modeled using a 5 unit and a 31 unit building and cost estimates were provided by Steve Pitkin, construction project manager and cost estimator. See 'MeasureCost_StevePitkin6-15-11.xls' for more information. Clearly the incremental cost per unit is much higher for smaller buildings than larger buildings so the per unit cost assumptions are extrapolated for different building sizes assuming a linear relationship.

High-Performance Incremental Costs

	Incremental Cost Assumption (EVT Certified to High-Performance) per unit					
Number of Units	1-5	6-10	11-15	16-20	21-25	26+
Staged 95% AFUE gas boilers	$0	$1	$2	$4	$5	$6
Staged 91% AFUE oil boilers	$840	$698	$555	$413	$271	$128

Staged 85% AFUE pellet boilers	$1,760	$1,711	$1,661	$1,612	$1,562	$1,513
Indirect DHW off a 95% gas boiler	$0	$0	$0	$0	$0	$0
Indirect DHW off a 91% oil boiler	$0	$0	$0	$0	$0	$0
Central AC - 15 SEER, 12.5 EER (CEE T2)	$220	$187	$154	$121	$88	$55
3 ACH50 (0.4 cfm50/sq ft)	$767	$679	$591	$502	$414	$325

These costs will be included above the EVT Certified level costs if these measures are included in the project.

O&M Cost Adjustments

Fossil Fuel Description

Footnotes

Outdoor Reset Control

Measure Number: III-F-4 a
Portfolio: 74
Status: Active
Effective Date: 2012/1/1
End Date: [None]
Program: Multifamily
End Use: Space Heating

Referenced Documents

- http://www.heat-timer.com/en/EducationDetail.aspx?Id=3
- boilerResetFactSheet
- OutdoorResetARCreduced

Description

A boiler outdoor reset control regulates the boiler water temperature used for space heating, reducing the temperature when the outside temperature is higher, during fall and spring, improving boiler efficiency and reducing heat loss off the circulating loop. Outdoor reset controls are typically standard on high efficiency gas boiler models, but are an add on for oil boiler units. This measure characterization documents additional savings that will be claimed when an efficient boiler is installed in place of a baseline model without the controls. The AFUE rating used to claim savings for this upgrade (in the Comprehensive Thermal Measure) does not capture savings associated with the Outdoor Reset Control. Note that if specifics from the installation are available (i.e. the length and insulation level of the circulating loop, the boiler size and run time), then a custom tool will be used to capture site specific savings.

Estimated Measure Impacts

Algorithms

Fossil Fuel Savings

If specifics from the installation are available (i.e. the length and insulation level of the circulating loop, the boiler size and run time), then a custom tool will be used to capture site specific savings.

$$\Delta MMBtu = SF \times \text{Annual Heat Load}$$

Where:

ΔMMBtu =

Annual Heat Load = Annual Heating Load of building served by boilers (MMBtu/year)
= Custom (based on heating load result from modeling)

SF = Savings Factor for Boilers with Outdoor Reset control
= 5%[1]

Baseline Efficiencies

Standard boiler without outdoor reset control.

High Efficiency

Boiler with outdoor reset control.

Operating Hours

Load Shapes

n/a. No electric savings.

Net Savings Factors

Measures

SHECONTR	Improved space heating controls

Tracks [Base Track]

6018LINC [is base track]	LIMF NC
6019MFNC [is base track]	MF Mkt NC

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
LIMF NC	6018LINC	SHECONTR	1.00	1.00
MF Mkt NC	6019MFNC	SHECONTR	1.00	1.00

Persistence

The persistence factor is assumed to be one.

Lifetimes

15 years

Analysis period is the same as the lifetime.

Measure Cost

Outdoor reset control is standard on high efficiency gas boiler models. The incremental cost of this measure is therefore assumed to be $0, since the incremental cost of the boiler is captured in the Comprehensive Thermal measure.

For high efficiency oil boiler models, outdoor reset controls are not standard but an optional add on. For oil boilers therefore the incremental cost is assumed to be $1000[2].

O&M Cost Adjustments

Fossil Fuel Description

Footnotes

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[1] Conservative estimate based on a number of sources:

1. "5%"; http://www.dteenergy.com/pdfs/boilerResetFactSheet.pdf
2. "15% or more"; http://www.heat-timer.com/en/EducationDetail.aspx?Id=3
3. "5 to 30%"; http://www.arcmech.com/images/fm/pdir17/OutdoorResetARCreduced.pdf

[2] Based on EVT conversations with local HVAC contractors.

ENERGY STAR Dishwasher

Measure Number:	VI-H-1 h
Portfolio:	EVT TRM Portfolio 2017-07
Status:	Active
Effective Date:	2018/1/1
End Date:	[None]
Program:	Residential New Construction
End Use:	Dishwashing

Update Summary

The ENERGY STAR Dishwasher measure has been updated according to the 3-year reliability review schedule.

Referenced Documents

- DEER2014-EUL-table-update_2014-02-05.xlsx
- ACEEE_Better Appliances_May 2013
- EVT_ENERGY STAR Dishwasher_Analysis_June2017_v4

Description

A standard or compact dishwasher meeting the ENERGY STAR/CEE Tier 1 efficiency specifications is installed in place of a model meeting the federal standard..

Algorithms

Electric Demand Savings

ΔkW = ΔkWh / (Ncycles × Hours/Cycle)

Symbol Table

Electric Energy Savings

ΔkWh = ((kWh_Base - kWh_EE) × %Electric_DHW) + ((kWh_Base - kWh_EE) × %Dishwasher × (%Fuel_DHW, oil + %Fuel_DHW, propane + %Fuel_DHW, natural gas))

Symbol Table

Fossil Fuel Savings

ΔMMBtu = ((kWh_Base - kWh_EE) × %DHW × 3,412 × ηElectric_DHW / ηFuel_DHW) / 1,000,000

Symbol Table

Water Savings

ΔCCF = (Gallons/Cycle_Base - Gallons/Cycle_EE) × Ncycles / 748

Where:

%DHW = Percentage of total energy consumption used for water heating (deemed, dependent on dishwasher type)

Dishwasher Type	%DHW[3]
Standard	45%
Compact	54%

%Dishwasher = Percentage of total energy consumption used for dishwasher operation (deemed, dependent on dishwasher type)

Dishwasher Type	%Dishwasher[3]
Standard	55%
Compact	46%

%Electric_DHW = Percentage of DHW savings assumed to be electric (deemed)

= 24%[4]

%Fuel_DHW = Percentage of DHW savings assumed to be non electric (deemed, dependent on DHW fuel type)

DHW Fuel Type	%Fuel_DHW[4]
Oil	10%

Natural Gas	14%
Propane	52%

ΔCCF = Customer water savings in hundreds of cubic feet for the measure (output)

See Reference Tables section for deemed savings values.

ΔkW = Gross customer connected load kW savings for the measure (output)

See Reference Tables section for deemed savings values.

ΔkWh = Gross customer annual kWh savings for the measure (output)

See Reference Tables section for deemed savings values.

ΔMMBtu = Gross customer annual MMBtu savings for the measure (output)

See Reference Tables section for deemed savings values.

ηElectric_DHW = Recovery efficiency of electric water heater (deemed)

= 0.98[7]

ηFuel_DHW = Recovery efficiency of fuel water heater (deemed, dependent on DHW fuel type)

DHW Fuel Type	ηFuel_DHW[8]
Oil	0.80
Natural Gas	0.74
Propane	0.84

1,000,000 = Conversion factor from Btu to MMBtu (constant)

3,412 = Conversion factor from Btu to kWh (constant)

748 = Conversion factor from gallons to CCF (constant)

Gallons/Cycle_Base = Amount of water (gallons/cycle) used by baseline dishwasher (deemed, dependent on dishwasher type)

Dishwasher Type	Gallons/Cycle_Base[5]
Standard	5.0
Compact	3.5

Gallons/Cycle_EE = Amount of water (gallons/cycle) used by efficient dishwasher (deemed, dependent on dishwasher type)

Dishwasher Type	Gallons/Cycle_EE[6]
Standard	3.15
Compact	2.63

Hours/Cycle = Dishwasher runtime (hours) per cycle

= 2.1 hours[1]

kWh_Base = Annual energy consumption of baseline dishwasher (deemed, dependent on dishwasher type)

Dishwasher Type	kWh_Base[5]
Standard	307
Compact	222

kWh_EE = Annual energy consumption of efficient dishwasher (deemed, dependent on dishwasher type)

Dishwasher Type	kWh_EE[6]
Standard	259.0
Compact	181.6

Ncycles = Number of dishwasher cycles per year (deemed)

= 175 cycles/year[2]

Baseline Efficiencies

The baseline reflects the minimum federal efficiency standards for dishwashers effective May 30, 2013, as presented in the table below.

Dishwasher Type	Maximum kWh/year	Maximum gallons/cycle
Standard	307	5.0

Compact	222	3.5

High Efficiency

The efficient equipment is defined as a dishwasher meeting the efficiency specifications of ENERGY STAR version 6.0, effective January 29, 2016, which are indentical to CEE Tier 1 specifications.

Dishwasher Type	Maximum kWh/year	Maximum gallons/cycle
Standard (≥ 8 place settings + six serving pieces)	270	3.5
Compact (< 8 place settings + six serving pieces)	203	3.1

Operating Hours

Load Shapes

8a Residential DHW conserve

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
8	Residential DHW conserve	Active	48.7 %	29.1 %	14.3 %	7.9 %	40.1 %	20.3 %

Net Savings Factors

Measures

CKLSEDRP	Energy Star Dishwasher Standard
CKLCEDRP	Energy Star Dishwasher Compact

Tracks [Base Track]

6038VESH [is base track]	RNC VESH

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
RNC VESH	6038VESH	CKLSEDRP	0.90	1.10
RNC VESH	6038VESH	CKLCEDRP	0.90	1.10

Persistence

The persistence factor is assumed to be one.

Lifetimes

11 years[9]

Analysis period is the same as the lifetime.

Measure Cost

Dishwasher Type	Baseline Cost	ENERGY STAR Cost	Incremental Cost[10]
Standard	$255.63	$331.30	$75.67
Compact	$290.13	$308.62	$18.49

O&M Cost Adjustments

There are no operation and maintenance cost adjustments for this measure.

Fossil Fuel Description

Fossil fuel savings are presented for each dishwasher type in the Reference Table section below.

Reference Tables

Savings for each dishwasher type are presented in the table below.[11]

	Dishwasher Type	
Savings Type	**Standard**	**Compact**
ΔkWh	31.7	23.6
ΔkW	0.08549	0.06373
ΔMMBtu (oil)	0.0089	0.0092
ΔMMBtu (natural gas)	0.0135	0.0139
ΔMMBtu (propane)	0.0445	0.0457
ΔCCF (water savings)	0.43	0.20

Footnotes

[1] Average cycle length for all dishwasher models reviewed by Consumer Reports in 2012, from ACEE and ASAP, "Better Appliances: An Analysis of Performance, Features, and Price as Efficiency Has Improved," May 2013, Table 9, page 34.

[2] Dishwasher cycles per year based on 2015 Residential Energy Consumption (RECS) data for New England provided by the U.S. Energy Information Administration. See file EVT_ENERGY STAR Dishwasher_Analysis_June 2017_v4.xlsx for calculation details.

[3] %DHW and %Dishwasher based on data from U.S. DOE, Final Rule Life-Cycle Cost (LCC) Spreadsheet. See "%DHW" tab within file EVT_ENERGY STAR Dishwasher_Analysis_June 2017_v4.xlsx.

[4] Based on data received by Efficiency Vermont on 08/21/2017 from the upcoming NMR Vermont Residential Market Assessment.

[5] Federal appliance standards effective May 30, 2013

[6] Average of products available on ENERGY STAR qualified products list, June 2017. See "Per Unit Savings" tab within file EVT_ENERGY STAR Dishwasher_Analysis_June 2017_v4.xlsx.

[7] Review of AHRI database shows that electric water heaters have a recovery efficiency of 98%.

[8] ηFuel_DHW based on a weighted average of DHW system efficiencies in new homes in Vermont, from "Vermont Residential New Construction Baseline Study Analysis of On-Site Reports," February 13, 2013, Table 7-4, pages 97-99. See "Energy Savings" tab within file EVT_ENERGY STAR Dishwasher_Analysis_June 2017_v4.xlsx.

[9] Measure lifetime from California DEER. See file DEER2014-EUL-table-update_2014-02-05.xlsx.

[10] Costs are based on data from U.S. DOE, Final Rule Life-Cycle Cost (LCC) Spreadsheet. See "Costs" tab within file EVT_ENERGY STAR Dishwasher_Analysis_June 2017_v4.xlsx for cost calculation details.

[11] See file EVT_ENERGY STAR Dishwasher_Analysis_June 2017_v4.xlsx for savings calculation details.

Comprehensive Shell Measure Savings

Measure Number: VI-L-1 b
Portfolio: 81a
Status: Active
Effective Date: 2014/1/1
End Date: [None]
Program: Residential New Construction
End Use: Multiple

Referenced Documents

1. VT UDRH_Baseline2011_Input Data_MEDIAN-FINAL_121613.xlsx
2. VT UDRH_Baseline2011_REMv14.3_MEDIAN-FINAL_121613.udr
3. RNC UDRH 2013 Update_Memo to PSD_FINAL bm.docx

- VESH Requirements

Description

This measure characterization documents the methodology and key assumptions for comprehensive residential new construction savings due to thermal shell and mechanical equipment improvements. This characterization includes savings for heating, cooling and hot water end uses[1].

Estimated Measure Impacts

Algorithms

Demand Savings

Demand Savings $= Demand_{AsBuilt} - Demand_{UDRH}$

Symbol Table

Energy Savings

Energy Savings $= Energy_{AsBuilt} - Energy_{UDRH}$

Where:

$Demand_{AsBuilt}$ = REM/Rate modeled demand (kW) of the AsBuilt home
$Demand_{UDRH}$ = REM/Rate modeled demand (kW) of the UDRH home
$Energy_{AsBuilt}$ = REM/Rate modeled consumption (kWh and MMBtu) of the AsBuilt home
$Energy_{UDRH}$ = REM/Rate modeled consumption (kWh and MMBtu) of the UDRH home

Energy and demand savings will be calculated using the User Defined Reference Home (UDRH) feature in REM/Rate™. All Residential New Construction Projects will be modeled in REM/Rate™ to estimate annual energy consumption and demand for heating, cooling and hot water. Each project will be modeled a second time to a baseline[2] specification. The difference in modeled energy consumption and demand between the AsBuilt project and UDRH baseline models will be the savings for that project.

Baseline Efficiencies

The following table provides an overview of the UDRH baseline specification[3]. The efficiencies listed below for the Energy Code Plus and ENERGY STAR program tiers are a mixture of prescriptive program guidelines and mandatory prescriptive requirements. Mandatory requirements are noted with an asterisk. Each program home will be unique and may fall above or below the efficiency guidelines listed below. All homes must meet a minimum performance (HERS) target[4].

		Baseline Efficiency	**Above-Baseline Efficiency**	
		UDRH	***Energy Code Plus***	***ENERGY STAR***
Heating	Boiler, gas/prop	94.1 AFUE	85 AFUE*	

	Boiler, oil/kero	86.9AFUE		
	Furnace, gas/prop	87.0 AFUE	95 AFUE*	
	Furnace, oil/kero	83.0 AFUE	85 AFUE*	
Cooling	CAC	13 SEER	14.5 SEER*	
Heat Pump	ASHP	7.7 HSPF / 13 SEER	ENERGY STAR qualified*[5]	
	GSHP	3.1 COP / 11.24 EER		
Domestic Hot Water	Tank, gas/prop	0.62 EF	0.59 EF	
	Tank, oil/kero	0.49 EF	0.51 EF	
	Instant, gas/prop	0.82 EF	0.82 EF	
	Indirect, gas/prop	0.87 EF		
	Indirect, oil/kero	0.80 EF	N/A	
Air Leakage	Infiltration	3.4 ACH50	4 ACH50*	3 ACH50*
Thermal Shell	Insulation Grade[6]	2	2	1
	Ceiling	R-38	R-49	
	Above-grade walls	R-19	R-20	
	Foundation Wall	R-10	R-15	
	Slab-on-Grade	R-10	R-15	
	Frame floors	R-24	R-30	
	Windows	U - 0.34	U - 0.32*	

High Efficiency

See under Baseline Efficiency above.

Operating Hours

Load Shapes

7a Residential DHW insulation
11a Residential A/C
5b Residential Space heat

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
7	Residential DHW insulation	Active	31.7 %	34.9 %	15.9 %	17.5 %	100.0 %	100.0 %
11	Residential A/C	Active	0.7 %	2.8 %	53.3 %	43.2 %	0.0 %	82.9 %
5	Residential Space heat	Active	42.9 %	57.1 %	0.0 %	0.0 %	25.0 %	0.0 %

Net Savings Factors

Measures

TSHCOMPH	Comprehensive Thermal Measure REMRate Calculated H
TSHCOMPC	Comprehensive Thermal Measure REMRate Calculated C
HWECOMP1	Comprehensive Thermal Measure REMRate Calculated D

Tracks [Base Track]

6038VESH [is base track]	RNC VESH

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
RNC VESH	6038VESH	TSHCOMPH	0.95	1.10
RNC VESH	6038VESH	TSHCOMPC	0.95	1.10
RNC VESH	6038VESH	HWECOMP1	0.95	1.10

Persistence

The persistence factor is assumed to be one.

Lifetimes

25 years.

Analysis period is the same as the lifetime.

Measure Cost

$3,627[1188]

O&M Cost Adjustments

Fossil Fuel Description

Footnotes

[1] This comprehensive measure characterization replaces the following Residential New Construction measures: Heating Savings, Efficient Furnace Fan Motor, Central Air Conditioner, Space Cooling Savings, ES Central Air Conditioner, and Fossil Fuel Water Heater

[2] Baseline specifications are derived from the Vermont Residential New Construction Baseline Study Analysis of On-Site Audits Final Report, February 13, 2013. A new UDRH baseline will be submitted to DPS for review within three months of final updates to a new Vermont RNC baseline study.

[3] See Reference document VT UDRH_Baseline2011_Input Data_MEDIAN-FINAL_121613.xlsx for the detailed specification.

[4] Efficiency Vermont Residential New Construction Requirements and Specifications http://www.efficiencyvermont.com/docs/for_my_home/rnc/VESH_Requirements.pdf

[5] http://www.energystar.gov/index.cfm?c=products.pr_find_es_products

[6] Insulation grade refers to the quality of insulation installation. Research has shown insulation is typically installed poorly and not to manufacturer's specifications. This has a significant impact on energy performance of the insulation. Grade 1 (per manufacturer instructions) is required by ENERGY STAR Homes.

Prescriptive Approach to RNC Savings

Measure Number: VI-L-2 a
Portfolio: EVT TRM Portfolio 2017-04
Status: Inactive
Effective Date: 2017/1/1
End Date: 2018/12/31
Program: Residential New Construction
End Use: Multiple

Update Summary

Note that the savings values in this characterization may be considered to be placeholders for the final values for 2017. We will revise the savings values, retroactive to 1/1/2017, when the 2017 UDRH baseline has been finalized.

Referenced Documents

- RNC Rx Savings Assumptions_032117
- Rx Path and Shell Savings - RNC Proposal Final
- EstimatedCostandSavings_ESv3

Description

This measure is the counterpart to measure VI-L-1 b Comprehensive Shell Measure Savings in the EVT Residential New Construction Program. This characterizations captures the savings for a non HERS-rated path whereby savings are based on average per project savings of past program participants. This measure is comprised of comprehensive residential new construction savings due to thermal shell and mechanical equipment improvements. This characterization includes savings for heating, cooling and hot water end uses. For additional information and background refer to referenced document Rx Path and Shell Savings - RNC Proposal Final.

Currently this characterization applies only to Efficiency Vermont Certified Homes; High Performance Homes will continue to receive HERS ratings and savings for those homes (as well as for other homes that opt to have a HERS rating) will continue to be based on REM/Rate.

When the UDRH baseline in is updated, the savings values in this characterization will also be re-analyzed and revised accordingly.

Baseline Efficiencies

As defined by measure VI-L-1 b Comprehensive Shell Measure Savings

Efficient Equipment

As defined by measure VI-L-1 b Comprehensive Shell Measure Savings

Algorithms

Electric Demand Savings

The electric demand and energy savings are based on conditioned square footage of the home and heating system energy source. Homes that use fossil fuel for at least one of their heating systems (DWH or space heating) are categorized as "Fossil Fuel Homes." Homes that rely on electricity for all heating and cooling needs are categorized as "All Electric Homes." All-electric homes are treated separately since their prevalence in the market is known to be increasing. Treating them separately as opposed to using a blended sample of all homes will aid in more appropriate savings allocations as the marketplace continues to evolve. Refer to referenced document RNC Rx Savings Assumptions_032117 for the historic dataset and summary analysis.

Reductions in electric kW load are as follows, specified by the measure code they will be claimed against. HWECOMP1 captures comprehensive savings related to domestic hot water; TSHCOMPC captures comprehensive savings related to cooling; and TSHCOMPH captures comprehensive savings related to space heating.

Connected Load Reduction (kW)			
Conditioned Square Footage	Measure	Fossil Fuel Home	All Electric Home
<1500	HWECOMP1	0.00031	0.00628
	TSHCOMPC	0.27490	0.25531
	TSHCOMPH	0.38120	2.26088
1500-2249	HWECOMP1	0.00071	0.00802
	TSHCOMPC	0.41560	0.42399
	TSHCOMPH	0.24066	4.26958
2250-3000	HWECOMP1	0.00073	0.01374
	TSHCOMPC	0.50143	0.60554
	TSHCOMPH	0.28516	5.61051
>3000	HWECOMP1	0.00212	0.01435
	TSHCOMPC	0.84769	0.80111
	TSHCOMPH	1.03173	4.77417

Electric Energy Savings

Savings, based on the categorization described above, are as follows:

Electric Energy Savings (kWh)			
Conditioned Square Footage	Measure	Fossil Fuel Home	All Electric Home
<1500	HWECOMP1	1.7	33.9
	TSHCOMPC	143.7	121.7
	TSHCOMPH	585.8	3,153.2
1500-2249	HWECOMP1	3.8	40.7
	TSHCOMPC	241.0	139.2
	TSHCOMPH	517.9	6,437.8
2250-3000	HWECOMP1	3.9	79.7
	TSHCOMPC	295.1	172.8
	TSHCOMPH	641.1	9,463.9
>3000	HWECOMP1	11.5	77.4
	TSHCOMPC	486.2	293.0
	TSHCOMPH	1,705.6	6,840.5

Fossil Fuel Savings

Fossil fuel savings, based on the categorization described above, are shown in the table below. Savings will be matched and claimed based on site-specific fuel type (i.e., propane savings will be claimed for a heating system that uses propane).

Fossil Fuel Savings (MMBtu) [1]			
Conditioned Square Footage	Measure	Fossil Fuel Home	All Electric Home
<1500	HWECOMP1	-	-
	TSHCOMPC	-	-
	TSHCOMPH	12.7	-
1500-2249	HWECOMP1	-	-
	TSHCOMPC	-	-
	TSHCOMPH	25.7	-
2250-3000	HWECOMP1	-	-
	TSHCOMPC	-	-
	TSHCOMPH	33.6	-
>3000	HWECOMP1	-	-
	TSHCOMPC	-	-
	TSHCOMPH	49.4	-

Load Shapes

Loadshape 5a will be used to capture the coincident peak energy and demand savings attributed to measure code TSHCOMPH

Loadshape 7a will be used to capture the coincident peak energy and demand savings attributed to measure code HWECOMP1

Loadshape 11a will be used to capture the coincident peak energy and demand savings attributed to measure code TSHCOMPC

7a Residential DHW insulation
11a Residential A/C
5b Residential Space heat

Number	Name	Status	Winter On kWh	Winter Off kWh	Summer On kWh	Summer Off kWh	Winter kW	Summer kW
7	Residential DHW insulation	Active	31.7 %	34.9 %	15.9 %	17.5 %	100.0 %	100.0 %
11	Residential A/C	Active	0.7 %	2.8 %	53.3 %	43.2 %	0.0 %	82.9 %
5	Residential Space heat	Active	42.9 %	57.1 %	0.0 %	0.0 %	25.0 %	0.0 %

Net Savings Factors

Measures

TSHCOMPH	Comprehensive Thermal Measure REMRate Calculated H
TSHCOMPC	Comprehensive Thermal Measure REMRate Calculated C
HWECOMP1	Comprehensive Thermal Measure REMRate Calculated D

Tracks [Base Track]

6038VESH [is base track]	RNC VESH

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
RNC VESH	6038VESH	TSHCOMPH	0.95	1.10
RNC VESH	6038VESH	TSHCOMPC	0.95	1.10
RNC VESH	6038VESH	HWECOMP1	0.95	1.10

Lifetimes

25 years.

Analysis period is the same as the lifetime.

Measure Cost

$3,627[2]

Persistence

The persistence factor is assumed to be one.

Footnotes

[1] Note: historic savings data from Mar-2015 – Feb-2017 shows average negative savings for domestic hot water (Measure Code 'HWECOMP1'). The primary reason for this is a mismatch in EVT Rater Protocol and the User Defined Reference Home (UDRH) assumptions. 80% of the cases of negative DHW savings are associated with Indirect Storage tanks off a boiler. EVT Rater protocol uses AFUE * 0.75 for indirect tanks, while the UDRH calculation uses AFUE * 0.92, resulting in negative savings for all indirect storage tanks. These inconsistencies have been highlighted for review during the 2017 UDRH update. As an interim step zero energy savings will be assumed for the DHW measure code (HWECOMP1).

[2] Incremental costs above IECC 2009 taken from ENERGY STAR Qualified Homes, Version 3

Savings & Cost Estimate Summary (see Referenced Documents).

Low Flow Toilet

Measure Number: VI-M-1 a
Portfolio: EVT TRM Portfolio 2018-01
Status: Active
Effective Date: 2018/1/1
End Date: [None]
Program: Residential New Construction
End Use: Water Conservation

Update Summary

New measure

Referenced Documents

- U.S. Census Bureau_ACS Table DP04 Vermont_2015
- DeOreo_Residential End Uses of Water Study 2013 Update_2014
- EPA_WaterSense Labeled Products_Dec 2017
- WRF_Residential End Uses of Water Exec Summary_Apr 2016
- City of Fort Collins_Green Building Practice Summary_Mar 2011

Description

This measure characterizes the installation of a WaterSense labeled toilet in a new home.

Algorithms

Water Savings

Using the default assumptions provided below, water savings are:

$\Delta CCF = ((1.38 - 1.28) \times 5 \times 2.33 / 2.5 \times 365) / 748 = 0.23$ CCF

$$\Delta CCF = ((GPF_{base} - GPF_{low}) \times \#\ flushes \times \#\ people / toilets/home \times usedays/year) / 748$$

Where:

\# flushes = Average number of toilet flushes per person per day
= 5[1]

\# people = Average number of people per household
= 2.33[2]

ΔCCF = Gross customer annual water savings for the measure

748 = Constant to convert from gallons to CCF

GPF_{base} = Gallons per flush (gpf) of baseline toilet
= 1.38 gpf[3]

GPF_{low} = Flow rate (gpm) of low flow toilet
= 1.28 gpf[4]

toilets/home = Average number of toilets per household
= 2.5[5]

usedays/year = Days toilet is used per year
= 365

Baseline Efficiencies

The baseline is a toilet that uses 1.38 gallons per flush (gpf).[3]

Efficient Equipment

The efficient condition is a toilet that uses 1.28 gpf.[4]

Load Shapes

There are no loadshapes associated with this measure.

Net Savings Factors

Measures

WATLFTLT	Low flow toilet

Tracks [Base Track]

6038VESH [is base track]	RNC VESH

Track Name	Track Nr.	Measure Code	Free Rider	Spill Over
RNC VESH	6038VESH	WATLFTLT	1.00	1.00

Persistence

The persistence factor is assumed to be one.

Lifetimes

The measure life is assumed to be 30 years.[6]

Measure Cost

The incremental cost difference between a standard toilet and a WaterSense toilet is assumed to be $0.[7]

Footnotes

[1] Water Research Foundation, "Residential End Uses of Water, Version 2: Executive Report," April 2016, page 9.

[2] Weighted average household size of owner-occupied versus renter-occupied housing units ((71% * 2.42) + (29% * 2.12)) based on 2011-2015 American Community Survey 5-Year Estimates for Vermont. See reference file U.S. Census Bureau_ACS Table DP04 VT_2015.pdf.

[3] Weighted average using a total of 542 federal standard toilets (1.6 gpf, established by the Energy Policy Act of 1992) and a total of 1,070 WaterSense toilets (1.28 gpf) available on Home Depot and Lowe's websites during a January 2018 review.

[4] Efficient toilet flow rate is the average flow rate of tank-type, single-flush toilets on the WaterSense Labeled Products list as of December 4, 2017. See file EPA_WaterSense Labeled Products_Dec 2017.xlsx.

[5] Average number of toilets per home from the Water Research Foundation, "Residential End Uses of Water Study 2013 Update," 2014, page 128.

[6] Toilet lifetime from Wisdom Blake Home Inspections: http://www.metrohome.us/information_kit_files/life.pdf and ATD Home Inspection: http://www.atdhomeinspection.com/advice/average-product-life/ is 50 years. EVT caps measure lifetimes at 30 years.

[7] Measure cost assumption from City of Fort Collins, "Green Building Practice Summary," March 21, 2011, page 2. The document states "Information from the EPA WaterSense web site: WaterSense® labeled toilets are not more expensive than regular toilets. MaP testing results have shown no correlation between price and performance. Prices for toilets can range from less than $100 to more than $1,000. Much of the variability in price is due to style, not functional design."